# Roadmap for service implementation beyond initial deployment – Version 2021

## Deliverable 7 of sub-activity 4.4

## (Cooperative ITS Services Deployment Support)




**Version: 1.0**

**Date: 23rd of December 2021**

Co-financed by the Connecting Europe Facility of the European Union

# Document Information

### Authors

| Name | Organisation |
|---|---|
| Carlos Viktorsson | Sweco |
| Vishal Baid | Sweco |
| Clas Roberg | Swedish Transport Administration |
| Torsten Geißler | Federal Highway Research Institute (BASt) |
| Mikko Tarkiainen | VTT Technical Research Centre of Finland Ltd. |

### Distribution

| Date | Version | Dissemination |
|---|---|---|
| 27.10.20 | 0.1 | Template from Sub-activity coordination (BASt) to the Swedish Transport Administration and Sweco |
| 05.01.21 | 0.8 | Version based on input by the Swedish team to the EU EIP 4.4 working group for review |
| 27.08.21 | 0.85 | Version based on further input by the Swedish team and additional input by Mikko Tarkiainen and Torsten Geißler as well as comments by Anders Bak Sørensen, sent to the EU EIP 4.4 working group for review (mature draft version) |
| 12.11.21 | 0.90 | Version further developed after WebEx meeting 11.11.21 |
| 03.12.21 | 0.99 | Clean-up and comments resolved |
| 22.12.21 | 1.0 | Final version to the EU EIP 4.4 working group |

# Preface

## EU EIP

The EU ITS Platform (EU EIP) is the place where National Ministries, Road Authorities, Road Operators and partners from the private and public sectors of almost all EU Member States and neighbouring countries, cooperate in order to foster, accelerate and optimize current and future ITS deployments in Europe in a harmonized way. In order to foster cooperation and the necessary consensus between EU Member States, the EU ITS Platform will facilitate the establishment of a commonly understood state of the art and promoting the actual take-up of EU specifications, guidelines, best practices and/or methodologies.

## Sub-activity 4.4: Cooperative ITS Services Deployment Support

Sub-activity 4.4 aims at developing and providing deployment guidance to road authorities and operators on Cooperative ITS (C-ITS). It capitalizes on the results of preceding C-ITS-related activities developing a mechanism for setting up deployment guidance for road operators concerning C-ITS services. It aims at collecting and updating the lessons learned from recent pilots and deployment initiatives as well as at advising and guiding road operators and road authorities in dealing with potential implementation issues concerning C-ITS. In particular, business and operating model implications of C-ITS for all relevant stakeholders and hybrid communication concepts have been examined.

## This deliverable

This deliverable represents the result of the Sub activity 4.4's work to develop a roadmap for service implementation beyond initial deployment. The intended audience is mainly road operators and authorities. The primary purpose of the roadmap is to provide a scenario of the future development of C-ITS while presenting the most likely steps that will be needed to be taken beyond initial deployment in terms of nearer-term priorities and longer-term priorities for the coming decade.

The work has involved a look ahead at what is most likely the development of Cooperative Intelligent Transport Systems (C-ITS) the coming decade based on the current state of play and identified visions for its deployment primarily in Europe.

## List of Acronyms and Abbreviations

| Abbreviation | Explanation |
|---|---|
| 3GPP | 3rd Generation Partnership Project (consortium of telecommunications standard development organisations ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC) |
| 3GPP Release 14 | LTE based Cellular V2X standard release which was completed 2017. Covers a series of mission critical enhancements, LTE sidelink support for V2X services, eLAA, Uu 4 band Carrier Aggregation, narrow-band IoT. |
| 3GPP Release 15 | LTE based Cellular V2X standard release which was completed 2018. Contains update for Uu link (1024 QAM), refined eLAA, enhancements to NB IoT, and enhancements/fixes for sidelink V2X. |
| 5G NR V2X | 5G New Radio based Vehicle-to-Anything communication standardised by 3GPP Release 16 |
| CAM | Cooperative Awareness Message |
| CAD | Connected and Automated Driving |
| CCAM | Cooperative, Connected and Automated Mobility |
| CEN | European Committee for Standardisation |
| C-ITS | Cooperative Intelligent Transport Systems and Services, refers to transport systems, where the cooperation between two or more ITS sub-systems (personal, vehicle, roadside and central) enables and provides an ITS service that offers better quality and an enhanced service level, compared to the same ITS service provided by only one of the ITS sub-systems |
| C-Roads | European platform for harmonising C-I2X services and ensuring interoperability of C-ITS infrastructure implementations |
| C-V2X | Cellular-V2X or Cellular Vehicle-to-Everything). C-V2X is defined in 3GPP standard releases. C-V2X includes both cellular (e.g., LTEUu) and short range communication (e.g., LTE PC5). |
| Day 1 / 2 / 3+ | Successive C-ITS deployment phases of use cases and technologies |
| DSRC | Dedicated short-range communications (DSRC) is a wireless communication technology that enables vehicles to communicate with each other and other road users directly, without involving cellular or other infrastructure. |
| DENM | Decentralized Environmental Notification Message |
| ETSI | European Telecommunications Standards Institute |
| I2V | Infrastructure-to-Vehicle Communication |
| I2X | Infrastructure-to-Anything Communication |
| ITS | Intelligent Transport System |
| ITS G5 | European profile standard for communications in the 5 GHz band (based on IEEE standard 802.11/802.11p) |
| ISO | International Organisation for Standardisation |
| IVI | In-vehicle Information |

| | |
|---|---|
| LTE | Long Term Evolution is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. |
| LTE-V2X | LTE-based V2X communication (see C-V2X and 3GPP Release 14) |
| LZM | Day 1 V2I service to support the driver, fleet manager and road operator in the booking, monitoring and management of urban parking zones specific to freight vehicles. |
| MAP | Map Data |
| ODD | Operational design domain *(*ODD*).* Tech companies and automotive manufacturers use the idea of Operational Design Domain (ODD) to indicate where their Automated Driving Systems (ADS) can operate safely. By definition from SAE J3016, an ODD defines where the ADS is designed to operate. |
| OEM | Original equipment manufacturer |
| PKI | Public key infrastructure (PKI) |
| R-ITS-S | Roadside ITS Station |
| RSU | Roadside unit |
| RWW | Road Works Warning |
| SAE | SAE International, formerly named the Society of Automotive Engineers, is a standards developing organization in US and globally (www.sae.org) |
| SPAT | Signal Phase and time of traffic light |
| Uu-CSP | Uu Communication System Profile |
| V2C | Vehicle-to-Cloud (V2C) Communication form that leverages V2N access to broadband cellular mobile networks to offer data exchange with the cloud |
| V2I | Vehicle-to-Infrastructure Communication |
| V2N | Vehicle-to-Network Communication. As opposed to DSRC, LTE/5G for V2N operates in licensed cellular spectrum. |
| V2P | Vehicle-to-Pedestrian Communication |
| V2V | Vehicle-to-Vehicle Communication |
| V2X | Vehicle-to-Everything communication |
| WLAN | Wireless Local Area Network |

# TABLE OF CONTENTS


**1. Scope and objective 8**

1.1. C-ITS services – Day 1, Day 1.5 and beyond 9

**2. State of play 12**

2.1. Highlighted developments 13

2.1.1. NordicWay, NordicWay 2 and NordicWay 3 13

2.1.2. The Netherlands 14

2.1.3. Germany 15

2.1.4. France 17

2.1.5. Austria 17

2.2. Outside of Europe – U.S and China 18

**3. How different sources view the future 20**

3.1. Road authorities and operators 20

3.2. Industry driven perspectives 24

3.2.1. The C2C-CC roadmap 24

3.2.2. The 5GAA roadmap 28

3.2.3. The ERTRAC roadmap 32

3.3. The Euro NCAP roadmap 36

3.4. The CCAM Platform 36

**4. Setting a Strategy – Roadmap beyond initial deployment 38**

4.1. C-Roads operation in 2023 40

4.2. Developments towards CCAM in 2025 and beyond 42

4.3. Ways forward? 42

4.4. Recommendations 43

**5. References 45**

**Appendix 1: Communication technologies for C-ITS 48**

**Appendix 2: The CCAM evolution in Europe 50**

**Appendix 3: Taxonomies for CCAM 56**

**Appendix 4: Summary of analysed roadmaps 65**

# 1. Scope and objective

This report represents a deliverable within the European ITS Platform Cooperative ITS Services Deployment Support Sub activity A4.4. The intended audience is mainly road operators and authorities. The deliverable involves a look at what is most likely the development of Cooperative Intelligent Transport Systems (C-ITS) based on the current state and stated vision for its deployment primarily in Europe with a brief mention of its development in the U.S and in China. The main focus of the deliverable is to provide a roadmap on what will most likely be developed in relation to C-ITS in Europe. The road map is limited to describing an interim period of initial deployment of C-ITS within the next 5 years together with a longer horizon after initial deployment of 10 years.

One of the more important developments regarding the deployment of C-ITS concerns what spectrums to be used in order to connect vehicles, roadside infrastructure, people and wide area networks to enable safer, more efficient road transport. One important development has been the European Commission's decision to harmonise the 5.9 GHz spectrum band for real-time information exchange, which is envisioned to improve road and urban rail transport safety.[1] [2] Once real-time data is available from drivers, vehicle, infrastructure, and the general public there is a need for a communication solution (including business models) for access/sharing of data.

The EU member states are still divided on which C-ITS standard to use. A significant portion of the automotive industry favours LTE-V2X over rival approaches yet it is ITS G5 that is currently most favoured within European deployment, and it is the only technology available in produced vehicles in the EU (such as the VW golf, ID3 and ID4). Mobile technology is set to play a vital role in ITS in general, with the latest version of LTE standards (including LTE-V2X) – gradually evolving to 5G.[3] Wireless connectivity faces the greatest technical challenges but is seen as promising in terms of 5G, whose specification were released in 2020 by the 3rd Generation Partnership Project (3GPP) which are the ones overseeing the development of 5G.[4]

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020D1426&rid=2D, accessed 2020-12-16

[2] https://ec.europa.eu/digital-single-market/en/news/harmonisation-59-ghz-spectrum-band-real-time-information-exchange-will-improve-road-and-urban, accessed 2020-12-16

[3] https://www.gsma.com/spectrum/wp-content/uploads/2018/12/Spectrum-for-Intelligent-Transport-Systems.pdf

[4] Ericsson, "Connected Urban Transport: A New Approach to Intelligent Traffic Management," 2017, https://www.ericsson.com/en/internet-of-things/solutions/off-the-shelf-solutions/connected-urban-transport

## 1.1. C-ITS services – Day 1, Day 1.5 and beyond

Standardized C-ITS services are considered a key issue for addressing increased road traffic congestion and to reduce road fatalities for which the European Union has set ambitious reduction targets. These are services that should run seamlessly and be interoperable across the EU according to the European Commission (2017).[5]

The European Commission has launched what is called the C-Roads Platform to link C-ITS deployment activities, jointly develop and share technical specifications and to verify interoperability through cross-site testing. Initially created for C-ITS deployment initiatives co-funded by the EU, C-Roads is open to all deployment activities for interoperability testing.[6] Several Day 1 basic safety use cases have been analysed in the past and many of them have been deployed by now, according to the 5GAA Automotive Association (2019)[7] and proven by C-Roads.[8] Day 1 services are based on a set of standardized messages developed by the European Telecommunication Standards Institute (ETSI) [9] and the CEN/ISO[10] which have been used to implement a first set of use cases to increase traffic safety in general, such as road works warning, hazardous location notification, in-vehicle signage or intersection safety (ERTRAC, 2019).

Day 1 use cases and applications are not at this point linked to specific communication technologies. However, applications have different operational and functional requirements, such as different latency requirements which lead to a specific communication technology being used. One such example is the use of ETSI ITS-G5 technology communicating within the 5,9 GHz band (such as R-ITS-S) that is used for information exchanged between vehicles and infrastructure which require low latency and depend on reliable short-range communication.

[5] "A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility" European Commission, 2017. https://ec.europa.eu/transport/themes/its/c-its_en

[6] https://ec.europa.eu/transport/themes/its/c-its_en, accessed 2020-12-29.

[7] 5G Automotive Association (5GAA), "A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs – 5G Automotive Association," p.5, http://5gaa.org/news/the-new-c-v2x-roadmap-for-automotive-connectivity/, accessed 2020-12-06

[8] "C-Roads, With C-ITS towards safer roads in Europe", Press release 04.06.2021, https://www.c-roads.eu/fileadmin/user_upload/media/saferoadstoday/20210604_SafeRoadsTODAY_Press_Statement_fin.pdf, accessed 2021-08-06.

[9] https://www.etsi.org/, accessed 2021-08-25

[10] https://www.iso.org/, accessed 2021-08-25

**Table 1 Day 1 and Day 1.5 Services**

| Day 1 Services | Day 1.5 Services |
|---|---|
| Emergency electronic brake light | Off street parking information |
| Emergency vehicle approaching | On street parking information and management |
| Slow or stationary vehicle(s) | Park & Ride information |
| Traffic jam ahead warning | Information on AFV fueling & charging stations |
| Hazardous location notification | Traffic information and smart routing |
| Road works warning | Zone access control for urban areas |
| Weather conditions | Loading zone management |
| In-vehicle signage | Vulnerable road user protection (pedestrians and cyclists) |
| In-vehicle speed limits | Cooperative collision risk warning |
| Probe vehicle data | Motorcycle approaching indication |
| Alert wrong way driving | |

The following figures provide insight into verified C-ITS services and use cases according to C-Roads. It is also worth mentioning that parts of the deployment status is available via the European Commission's TENTec Portal.[11]

**Figure 1 Location in Europe of implemented Day 1-services**
**Source: C-Roads, 2020**[12]

[11] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html, accessed 2021-08-06.
[12] https://www.c-roads.eu/pilots/implemented-services.html, accessed 2020-12-30.

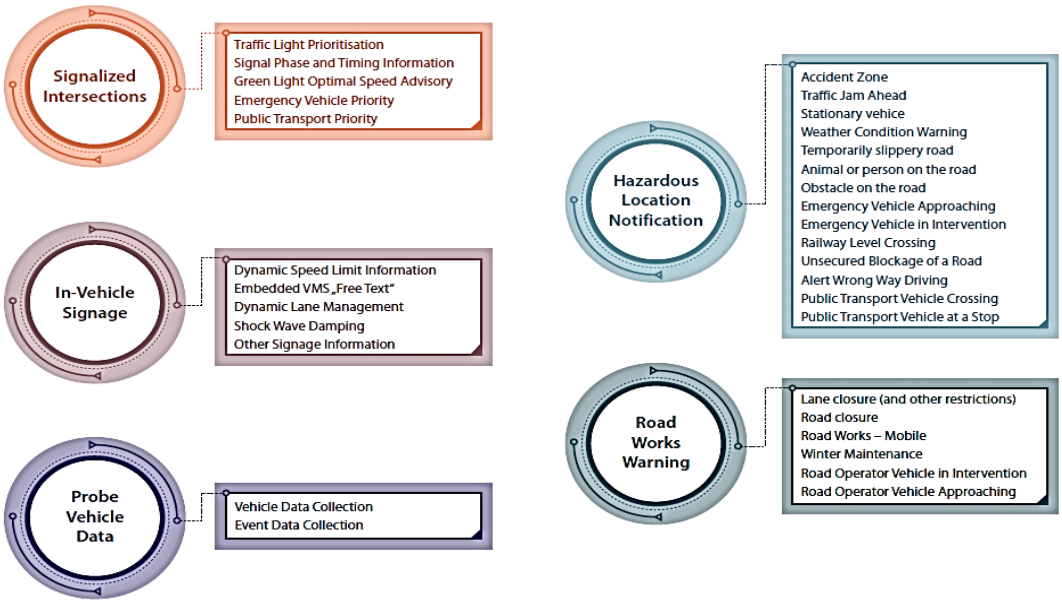



**Figure 2 Verified C-ITS services and use cases (Day 1, Day 1.5, Day 2) in the C-Roads Platform Source: C-Roads, 2021**

# 2. State of play

It is important to early point out that C-ITS use cases include complex interactions between vehicles, vehicles and infrastructure and also between autonomous vehicles. The C-ITS market is still in its early stages with road authorities and operators, particularly in Europe, still testing and preparing, in one form or another, for a deployment of C-ITS enabled services in their respective countries. According to the CAR 2 CAR Communication Consortium the deployment of C-ITS and ITS-G5 will mean that the first important step towards truly connected and automated driving has been taken.[13] The 5G Automotive Association (5GAA) have pointed out that that Basic System Profiles (BSP) will be needed in order to provide a common standard interpretation which outline basic system settings and environments.

In Europe BSPs have been developed by the Car-2-Car Communication Consortium (C2C-CC) and the EU-funded C-ROADS project, in which ITS-G5 with IEEE 802.11p as radio access technology has been assumed for V2V and V2I communication. In addition, there would be extensions required to accommodate alternative communications like V2P (Vehicle-to-Pedestrian (V2P), V2N (Vehicle to Network), and V2C (Vehicle to cloud).[14] Additionally there is the NordicWay[15] approach which is developed to support service interoperability in a C-ITS environment that is open, scalable and flexible and permits building on existing networks (e.g., cellular, IP-based) and hybrid environments via cloud based services.[16]

Some general observations of the current state of play indicate that:

- The most common view amongst those involved in C-ITS deployment is that it will be based on a smart mix of communication technologies involving ETSI ITS-G5 and cellular communication, potentially also others.
- There is currently two main vehicle-to-everything (V2X) technologies which are backed up by key players of various automotive, telecommunication and transport industries: one is the ITS-G5 and the other cellular vehicle-to-everything (C-V2X).
- Connectivity will play an important role towards automated driving. This relates to many issues connected to chosen communication solutions; such as security, latency and coverage issues.

[13] https://www.car-2-car.org/about-c-its/, accessed 2021-04-07

[14] 5G Automotive Association (5GAA), "5GAA Initial C-V2X System Profile (ICSP) – Amendments to C-ROADS Roadside System Profile," 2018.

[15] https://nordicway.net

[16] Flensholt, J. *et al.,* "NordicWay Service Definitions – Services and Use Cases", 2020 https://uploads-ssl.webflow.com/5c487d8f7febe4125879c2d8/5f574769b22ecf4ca01bc186_ServicesAndUseCases%20ver%201%201.pdf

- Many of the road authorities are engaged in multi-stakeholder coordination groups sharing knowledge from lessons learned that provide opportunities for cost-reduction.
- Europe is actively supporting international cooperation with regard to C-ITS.
- C-ITS implementation is driven by EU Member States (16 Members States) plus Norway and United Kingdom who are all engaged in national and cross-border pilots in close cooperation with industry
- The C-ITS implementation above addresses not only European road corridors but also urban nodes, with increasing number of cities involved as pilot sites
- Hybrid communication (ITS-G5 and cellular communication) is perceived as a priority. The view among many of the countries is that hybrid communications offer more flexibility in terms of implementation, particularly for V2I / I2V services.

The following section provides aggregated information on examples of C-ITS related deployment in Europe.

## 2.1. Highlighted developments

### 2.1.1. NordicWay, NordicWay 2 and NordicWay 3

NordicWay is an EU Connecting Europe Facility (CEF) funded pre-deployment pilot of Cooperative ITS (C-ITS) services in Sweden, Norway, Finland and Denmark which aims to support a wide-scale deployment of these type of services in Europe. Part of the objective is to further develop interoperable Day 1 and Day 1.5 services and support infrastructure readiness for connected and automated driving in Nordic conditions. Nordic conditions refers to the extensive road network of the Nordic countries with long distances, sparsely populated rural areas, and winter conditions. The NordicWay project aims towards making use of hybrid communication (cellular and ITS-G5) that mainly uses cellular communication, the development of an Interchange Node and Interchange Network (of nodes) which act as neutral servers supporting hybrid communication architecture distributing Safety Related Traffic Information (SRTI; EU/886/2013 delegated regulation) and the development of C-ITS messages and multiple other standard data models to exchange data between private and public partners.

The NordicWay 1 project (running between the years 2015 - 2017) demonstrated that the cellular communication network 3G and 4G/LTE are sufficient, both when it comes to latency and coverage for the piloted C-ITS services in Nordic conditions.

NordicWay 2 (running between 2017 - 2020) continued where NordicWay 1 left off and enhanced the cooperation between public and private stakeholders in order to build a common understanding of what is needed in the area of data communication with regard to future digital and physical infrastructure requirements. A first development consisted of a federated network of interchange node connection which was successfully established and demonstrated (in a Nordic Tour driving demo across all Nordic countries). An ecosystem with over 30 public and private partners supporting the OEMs and service providers' customers' relationships was envisioned as achievable in order to provide for innovative services. Several pilots have been deployed via a collaboration between service providers, government authorities, technology providers and OEMs together with thousands of live users during the tests. Future business models and the role of public authorities is still unclear for full deployment.

Technical evaluation results have confirmed technical feasibility and scalability of the Interchange network with low latencies. Apart from proving the technical concept of C-ITS-services, the project focused on the organisational, legal, and social aspects of a future connected road transport system. NordicWay 2 provided a valuable platform for such discussions on roles and responsibilities between public and private stakeholders.[17] Even though the implementation of C-ITS services in Europe has started, further cooperation is still needed. To achieve a harmonized and interoperable ecosystem, areas related to procurement process and operational aspects will have to be addressed. This is part of the goal of the EU CEF funded NordicWay 3 project which is ongoing since 2019.

All NordicWay projects results including related to issues such as user acceptance, technical, ecosystem and socio-economic evaluations as well as pilot reports are all available on the NordicWay webpage.[18]

### 2.1.2. THE NETHERLANDS

A policy has been adopted for a transition programme (running between 2013-2023) where the collective traffic information and management will be extended with individual traffic information offering possibilities for individual traffic management. The goal is to achieve a reduced investment in conventional roadside systems when the approach is proven to be feasible as a joint public-private cooperation. According to the Amsterdam Group (2013) the 'PraktijkProef Amsterdam' (PPA: pilot Amsterdam on network management and in-car services) and the Corridor project Netherland-Germany-Austria serve as important deployment tests to demonstrate and prove the added value of in-car

[17] Satu Innamaa, "NordicWay 2 Evaluation Report," 2020, https://www.nordicway.net/.
[18] https://www.nordicway.net/, 2021.

services on a large scale. Important criteria are scalability, continuity, cross-border, cost efficiency, portability, and acceptance/appreciation by road-users according to them.[19]

The Day 1 services will be related to the communication in the InterCor[20] project. In terms of the status of Day 1 services and applications some of them have been partially deployed or will be deployed through cellular services. The status of Day 1.5 services and applications are considered to be partly achieved. Most of the services are provided through cellular based solutions, into vehicle through mobile services or via apps. Related to this there is a framework for the safety element of traffic information services to be used as a guidance for app-based services, and how local apps can be designed. The coordinator is the Dutch Rijkswaterstaat.

There are currently proof of concepts (PoC) such as the Dutch development and testing of the exchange of SRTI messages between private and public partners[21] connecting all involved parties via short range communication with the option to support hybrid profiles and different media in order to be more compatible and interoperable.[22]

### 2.1.3. GERMANY

The Federal Government strategy for Automated and Connected Driving (2015) has been pivotal for numerous actions on developing the legal framework, promoting research and innovation as well as establishing digital test beds.[23] The Automated Driving Round Table as an interdisciplinary and cross-institutional expert body coordinated by the Federal Ministry of Transport and Digital Infrastructure has proved its worth as a central platform for societal participation. An implementation report is available summarizing the achievements of the 18th legislative period (ending 2017).[24]

[19] Amsterdam Group, “Road Map,” Amsterdam Group, 2013, http://amsterdamgroup.mett.nl/Road+Map/default.aspx.

[20] InterCor (Interoperable Corridors) is a European project which aims to connect the C-ITS corridor initiatives of the Netherlands C-ITS Corridor (Netherlands-Germany-Austria), the French corridor defined in the SCOOP@F project, and United Kingdom and Belgian C-ITS initiatives. The project plans to achieve a sustainable network of C-ITS corridors providing continuity and serving as a TestBed for Day-One C-ITS service development and beyond, https://intercor-project.eu/

[21] During the PoC, approximately 28 million messages were received by the Dutch National Access Point only. Vehicle data contributed to five out of the eight Safety Related Traffic Information categories. However, the categories that cannot be detected by vehicle data at this point in time, might be available at public parties and other industry partners.

[22] https://www.dataforroadsafety.eu/proof-of-concept, accessed 2020-12-23

[23] https://www.bmvi.de/SharedDocs/EN/publications/strategy-for-automated-and-connected-driving.html, accessed 2021-11-16.

[24] https://www.bmvi.de/SharedDocs/EN/Documents/DG/report-implementation-of-acd-strategy.pdf?__blob=publicationFile, accessed 2021-11-16.

Germany operates successfully its Mobility Data Marketplace (MDM, via the webpage: https://www.mdm-portal.de/) for almost a decade now which contributes to making data available, lowering the transaction costs of exchanging data while not intervening in the market relations. In spring 2022, its successor Mobilithek (referring to a form of "mobility library") will replace the MDM as the National Access Point (NAP) for mobility data while implementing requirements from the Delegated Regulations of the European ITS Directive and the amended Carriage of Passengers Act. Beginning in 2023, the MDM and mCLOUD (BMVI open data portal) will gradually be merged into Mobilithek which will play a key role in providing for a comprehensive mobility data ecosystem. Through its cloud-based infrastructure with a web portal, high-performance support for real-time data exchanges and a digital space for developing data-based apps, it will cooperate closely and share data with the Mobility Data Space, which is currently also under development. It is envisioned that the International Data Space (IDS) technology used by both systems will make this possible.[25]

Germany is involved in the C-Roads flagship project. The C-ITS Corridor stretching from the Netherlands to Austria has been instrumental in bringing Day 1 services – most notably Road Works Warning – into regular operation.[26] The first wave (C-Roads Germany, 2016-2021) has aimed at piloting a broader bundle of C-ITS services in motorway conditions in Hessen and Lower Saxony. C-Roads Germany Urban Nodes (2019-2023) puts the emphasis on urban C-ITS services with test sites in Hamburg, Kassel and Dresden.[27] There are many more test beds, including e.g., Düsseldorf and Munich where an initiative has been started by the City of Munich and the state of Bavaria to set up a test-bed for cooperative traffic lights. The aim is to test all existing communication channels (ITS G5, LTE-V2X, and backend with service providers). Within the initiative "Digital test-bed Autobahn", the state of Bavaria has also made available the content of variable message signs to enable services like in-vehicle signage, in-vehicle speed limit and smart routing. The data can be subscribed from via the Mobility data marketplace.

More generally, digital test beds in the public road environment are an essential element of the Federal Government's research and innovation funding. Examples of motorway test beds are the Digital Motorway Test Bed (A9) and the Franco-German-Luxembourg Digital Test Bed. There is also a substantial number of urban and rural testbeds. Information on all testbeds is available from a dedicated website (Testfeldmonitor).[28]

[25] https://www.bmvi.de/SharedDocs/EN/Articles/DG/mobilithek.html, accessed 2021-11-16.
[26] https://c-its-deployment-group.eu/activities/c-its-deployments/, accessed 2021-11-16.
[27] More information available at https://www.c-roads-germany.de/english/, accessed 2021-11-16.
[28] https://www.testfeldmonitor.de/Testfeldmonitoring/DE/Home/home_node.html, accessed 2021-11-16.

As C-ITS enabled data involves privacy issues, Germany has established as of 2021 a legal basis for gathering, saving and using such data for traffic management purposes (§63e StVG Road Traffic Act).[29]

### 2.1.4. FRANCE

France has been working since 2014 with its Scoop@F project [30], a project that focuses on most of the Day 1 services and applications. The project has worked with the whole eco system including those of the road manufactures. Another major project France is involved in is the previously mentioned InterCor project, linking the C-ITS corridor initiatives of the Netherlands (C-ITS Corridor NL-DE-AT) with the French SCOOP@F project and extending to the United Kingdom and Belgium C-ITS initiatives.

C-Roads France is a C-ITS pilot deployment project set up by 13 French beneficiaries covering the whole functional chain of C-ITS systems and services, including most partners of SCOOP@F but also cities, new road operators and academic partners. The project includes four pilot sites: North-East, Center-East, West and South-West.[31]

The main objective of the project has been to develop and experiment with innovative road C-ITS solutions towards a seamless continuity of services at the urban/interurban interface.

### 2.1.5. AUSTRIA

Austria has been working since 2016 together with the Netherlands and Germany to implement C-ITS services along a corridor from Rotterdam via Frankfurt/Main to Vienna. The Austrian part of this corridor will be defined in the project ECo-AT ("European Corridor – Austrian Testbed for Cooperative Systems"). In the first phase a complete system specification will be developed, tested and approved. This specification will be the basis for subsequent tenders for C-ITS units on Austrian motorways. The goal has been to have defined "Day 1 applications" available along the corridor. These applications will be "Roadworks Warning", "In-Vehicle Information", "Probe Vehicle Data", "SPAT / MAP applications" and certain "DENM applications".

[29] For information see https://www.gesetze-im-internet.de/stvg/BJNR004370909.html, accessed 2021-11-16.

[30] SCOOP is a C-ITS deployment project in Europe built on a cooperation between road managers and car manufacturers addressing issues such as privacy, cybersecurity, industrial processes, calls for tenders, compliance audit, and interoperability. http://www.scoop.developpement-durable.gouv.fr/en/

[31] https://www.c-roads.eu/pilots/core-members/france/Partner/project/show/c-roads-france.html, accessed 2021-12-10

Since November 2020 the Austrian motorway operator ASFINAG has started implementing V2X by deploying the related technology and solutions on selected sections in order to expand it to the overall Austrian motorway network within the next few years.[32]

## 2.2. Outside of Europe – U.S and China

The U.S. Federal Communications Commission adopted in November 2020 new rules for the 5.9 GHz band (5.850-5.925 GHz) to make new spectrum available for unlicensed uses, such as Wi-Fi, and improve automotive safety. Specifically, the new band plan designates the lower 45-megahertz (5.850-5.895 GHz) for unlicensed uses and the upper 30 megahertz (5.895-5.925 GHz) for enhanced automobile safety using Cellular Vehicle-to-Everything (C-V2X) technology. Under the new rules, ITS services will be required to vacate the lower 45 megahertz of the band within one year. The decisions have relevance for how to transition ITS operations in the band to C-V2X-based technology, including the appropriate implementation timeline and technical and operational parameters for C-V2X service.[33]

In China, 5905-5925 MHz (20 MHz) is currently allocated for use by LTE-V2X direct communications for the delivery of ITS services, with the lower 10 MHz block for Vehicle to Vehicle (V2V) communications, and the upper 10 MHz block for Vehicle to Infrastructure (V2I) communications.[34] The Chinese government and Society of Automotive Engineers of China (SAEC) together with the "China Industry Technology Innovation Strategic Alliance for Intelligent and Connected Vehicles" have issued a roadmap for intelligent and connected vehicles that according to the European Road Transport Research Advisory Council, ERTRAC (2020) "could have semi- or fully autonomous vehicles on sale as early as 2021".[35]

China is aiming towards what they call a technical leadership in "intelligent vehicles" in which they already in October 2016 released their "Technology Roadmap for Energy-Saving and New Energy Vehicles". The roadmap includes intelligent and connected vehicles (ICV) as an important future mobility solution aiming at an ambitious installation rate for driving assistance and partial autonomous driving of 50% by the year 2020, 10% -

[32] C-ROADS, "Press Release: ASFINAG Connects Roads with Vehicles on a Large Scale in Europe: C-Roads," 2020, https://www.c-roads.eu/platform/about/news/News/entry/show/press-release-asfinag-connects-roads-with-vehicles-on-a-large-scale-in-europe.html.

[33] https://www.fcc.gov/document/fcc-modernizes-59-ghz-band-improve-wi-fi-and-automotive-safety

[34] https://5gaa.org/wp-content/uploads/2020/09/A-Visionary-Roadmap-for-Advanced-Driving-Use-Cases-Connectivity-Technologies-and-Radio-Spectrum-Needs.pdf

[35] ERTRAC (European Road Transport Research Advisory Council), "Connected Automated Driving Roadmap", 2020

20% highly automated vehicles in 2025 and 10% full automation by the year 2030. The Chinese government has stressed the need for such a development of intelligent connected cars in order to reduce the number of traffic accidents by more than 30 percent by establishing an autonomous driving speed of 120 km/h while also reducing energy consumption by more than 10 percent and greenhouse gas emissions by more than 20 percent. A specific draft for a “Strategy for Innovation and Development of Intelligent Vehicles” was published by the National Development and Reform Commission (NDRC) in January 2018 and includes a 3-phase vision for CAD development.

# 3. How different sources view the future

While many C-ITS related pilot projects have shown that cooperative systems work at a technical level, there is still a need to provide evidence of how real benefits for road authorities and local authorities can be gained, such as how they can contribute to either policy objectives and/or cost-effectiveness.[36]

Cybersecurity, interoperability and collaboration is perceived as central issues for the development of C-ITS and CCAM. Standards are part of this aspect and are being developed by actors such as ETSI, CEN and 3GPP while necessary profiles for its use are being published by C-Roads, C2C-CC and 5GAA. Standards alone are not enough to ensure interoperability or collaboration since a shared understanding and consistent interpretation of technologies, applications and what is defined as a useful standard will be necessary in order to provide benefits to all stakeholders.

There are also different views on how the future will look like connected to C-ITS and its role for automation. Although C-ITS supports automated vehicles in a variety of situations, fully automated vehicles are not yet within reach as of yet. There are however various projects working on traffic management measures and digital infrastructure adaptations to support automated mobility where C-ITS has a key role.

## 3.1. Road authorities and operators

Before looking at the relevant strategic and roadmap documents of the automotive and the telecom sector it is appropriate to take stock of the road authorities and road operators internal positioning and plans towards the future. To that end several documents are briefly reconsulted. They all have in common a forward looking attitude and approach.

The 2016 report "C-ITS Deployment Preparation for road authorities and operators, Deliverable 2 of EIP+" included questions on the expectations on the C-ITS technology and services level of adoption in five or ten years which would imply the years 2021 and 2026.[37] Statements from the report highlight that:

- The majority of the road authorities expect a widespread use of C-ITS in daily operation especially for certain services like the Day 1 applications.

[36] Amsterdam Group, "Road Map," Amsterdam Group, 2013, http://amsterdamgroup.mett.nl/Road+Map/default.aspx.

[37] Berndt, S., *et al.,* "C-ITS Deployment Preparation for road authorities and operators, Deliverable 2 of EIP+ Activity 4.1", 2016.

Remaining concerns are the dependence on the number of equipped vehicles and thus on the automotive industry as well as the dissemination only on specific corridors, which demonstrates that organizational and business aspects are decisive for the level of adoption.

- An even more widespread use is expected, including Day 2 C-ITS applications, paving the way to automation levels of Level 3 and more although the prospects include “all national and local roads” to “only along certain key routes”.

The views above are reconfirmed in the 2019 report “White Paper for future C-ITS service implementation – Roles and Responsibilities” where specific statements have been gathered from road authorities in particular concerning use case-based views on the role between public and private actors.[38]

A subsequent “D4 Roadmap” report in 2020 from the European ITS Platform (EU EIP) addresses the policy side of C-ITS deployment in a Corridor network.[39] The report highlights the role digital infrastructure will play in which the concept of digital twins will become increasingly important. It foresees a need to discuss the concept of digital twins and their required properties among potential stakeholders which it envisions will need to agree on a common view on digital twins with regard to development, operation and management needs. The main emphasis of the EU EIP roadmap is on actions that road authorities and operators have to take in order to enable automated driving on the roads that they are responsible for.[40]

The **MANTRA project (CEDR Transnational Research Program**)[41] consortium forecasts highly automated driving use cases in vehicle fleets by assessing the impacts of automated driving in relation to traffic flow, infrastructure, and road authority core business. The MANTRA roadmap of 2020 contains a list of 92 actions in the domains of physical infrastructure, digital infrastructure, operations and services, and road planning and maintenance with regard to the possible impacts of highly automated driving by 2040, and their ODD-related requirements. ODD refers to an Operational Design Domain (ODD) to indicate where Automated Driving Systems (ADS) are designed to operate. MANTRA has put particular emphasis on following a use case-based approach (see figure below). The fourth bundle of use cases represents a clear add-on since it focuses

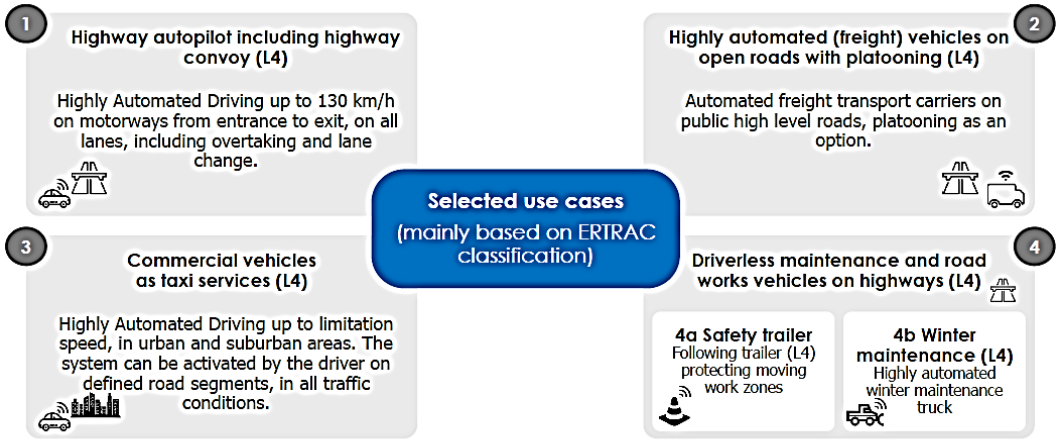
[38] Viktorsson, C., and Roberg, C., “White Paper for (future) C-ITS service implementation – roles and responsibilities for C-ITS, EU EIP Deliverable D3 of Sub-Activity 4.4”, 2019.

[39] Jonas Sundberg et al., “D4 Roadmap Recommended Actions for Core Network Corridor Digitalization.,” 2020.

[40] Amelink, M. et al., “Road map and action to facilitate automated driving on TEN road network – version 2020, Deliverable Task 3 of EU EIP”, 2020.

[41] MANTRA (Making full use of automation for National Transport and Road Authorities – NRA Core Business), Kulmala, R, et al., “Road map for developing road operator core business utilizing connectivity and automation, MANTRA Deliverable D5.2”, 2020.

on automation use cases from a road operators point of view. Safety trailers following moving work zones and highly automated winter maintenance trucks provide enhanced protection of work zones as well as significant operational benefits.




Together with PEB & CEDR CAD WG as part of the mini-workshop in Vienna (31.08.2018) and in more detail in Oslo (05.11.2018)

**Figure 3 Use cases on which the MANTRA roadmap and recommendations are based upon**

The overall view of the European road authorities and operators is underpinned and complemented by regional examples of how previous related strategies have evolved and in previous road mapping (the following figures illustrate this approach for Hessen Mobil in Germany).[42] [43] In the light of the recent organizational transformation of motorway operation in Germany (Autobahn GmbH des Bundes 2021) it becomes obvious that the illustrated development lines are instrumental for the motorways all over Germany. The strategic evolution aims at embedding the trends and needs of digitalizing road traffic and to complement coordinated action of road operators by embracing the elements of cooperation and automation.

[42] Riegelhuth, G., “Introduction – road operators strategy view”, Presentation at URSA MAJOR 2 Workshop “The interface from TMPs to navigation services, Frankfurt, 28.04.2016, www.its-platform.eu.

[43] Riegelhuth, G.,”The Strategy of Road Operators considering C-ITS Day 2+ services”, Car2Car Forum 2020, 2020-11-03.

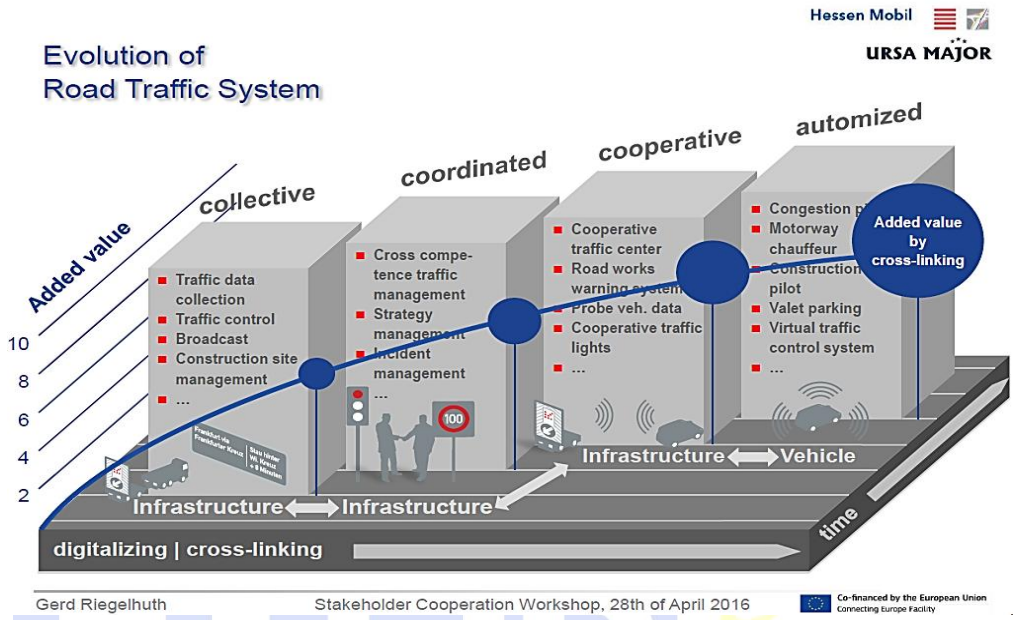



**Figure 4 Evolution of Road Traffic System (example from Hessen Mobil)**

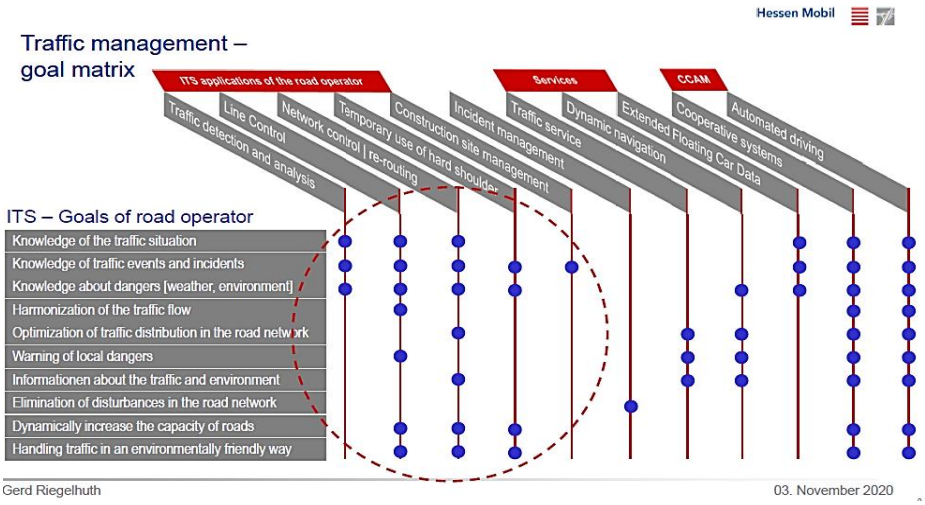



**Figure 5 From ITS applications to CCAM services**

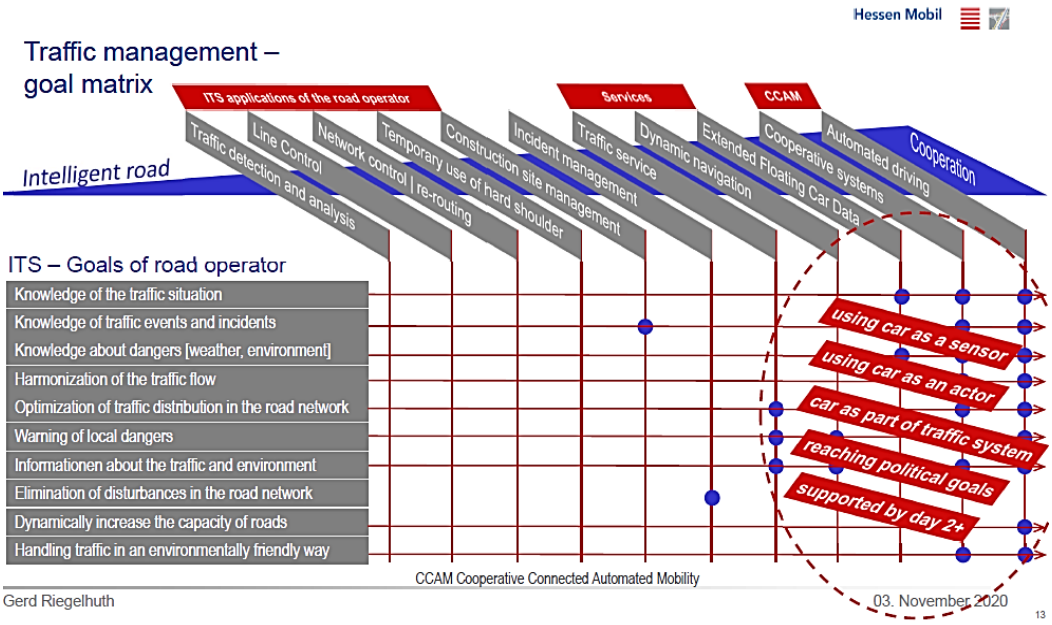



**Figure 6 Cooperation essential for CCAM services**

## 3.2. Industry driven perspectives

This subchapter presents three industry driven perspectives of multi-sector relevant roadmaps. Predominantly, it is apparent that industry aligns its strategy perspectives via umbrella organizations such as the Automotive Association (5GAA), the Car2Car Communication Consortium (C2C-CC) and the European Road Transport Research Advisory Council (ERTRAC). The selection used here does not aim at excluding industry umbrellas such as ACEA and GSMA but the ones presented here cover the entire bandwidth of topics relevant to C-ITS in this industry.

### 3.2.1. THE C2C-CC ROADMAP

The **CAR 2 CAR Communication consortium (C2C-CC)** views future technical innovations in C-ITS as welcomed but should be combined with what they call existing, proven technologies in order to complement what they see as a defined hybrid communication approach.[44]

[44] Press release, https://www.car-2-car.org/press-media/press-releases/press-details/c-its-deployment-takes-off-increasing-road-safety-and-decreasing-congestion-80/, October 2019.

ITS-G5 with a no network coverage or subscription required (particularly in the rural areas) together with cellular networks (3G/4G) may as a consequence be supported by future 5G developments that will, according to the consortium, provide Europe with further options for delivering technology. The consortium views such a technology neutral approach (i.e., by not forcing any subscription) as supporting the two “Cs” in Cooperative, Connected, and Automated Mobility (CCAM), which according to them should be the highest priority in Europe. The consortium views the deployment of C-ITS and ITS-G5 as the first important step towards truly connected and automated driving. The deployment phases (Day 1, Day 2, Day 3+…) are labelled and mapped by them – alongside sample use cases – according to communication services and message types as well as supporting functionalities such as security, misbehaviour detection and functional safety qualifiers.

The C2C-CC roadmap illustrates several dimensions of improvement throughout the deployment phases, comprising support from risks and info dissemination to coordinated automation, trustworthiness, accuracy (position and time) and timeliness. Services and use cases beyond Day 2 services deliver V2X services that assist vehicle automated functions relying on the knowledge of other vehicles’ intentions, trajectories, and manoeuvres.[45] Their roadmap timeline is less explicit compared to the 5GAA roadmap presented in the following chapter. However, as a rule of thumb, it can be expected that the move from one deployment phase to the next one takes at least five years which includes necessary time for both revising existing standards and developing new standards, together with any necessary preparation as well as profiling and testing.

[45] CAR 2 CAR Communication Consortium, “Guidance for Day 2 and beyond Roadmap,” Version 1.2, 2021.

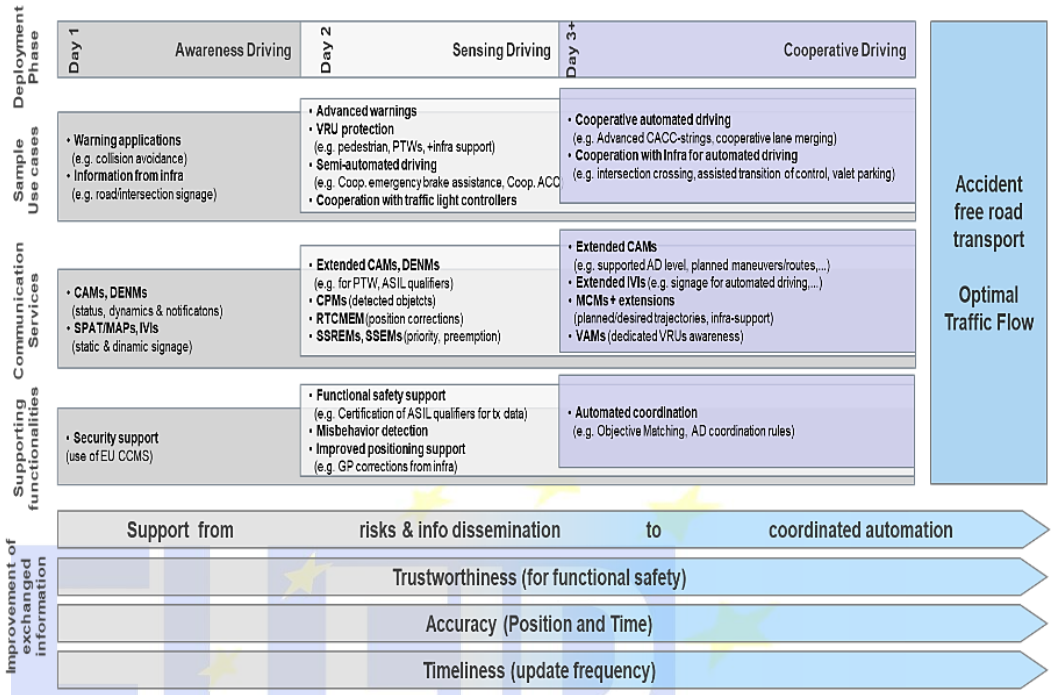



**Figure 7 C2C-CC Roadmap Evolution of connectivity and cooperation as enablers for automated driving Source: C2C-CC 2021**

The following table lists future use cases, which are relevant from a road operators' perspective as defined in the C2C-CC roadmap.[46] The table below provides use case name, description, role or data provided by infrastructure (usually managed by the road operator or authority), and the step defined in the source documents. The Day 1 use cases are not included in the table below as they are already currently being deployed in many places throughout Europe.

**Table 2 Future C-ITS use cases based on the C2C-CC**

| Use Case | Description | Role of (or data provided by) Infrastructure | Phase |
|---|---|---|---|
| **Long-term Road Works Warning (RWW)** | Road infrastructure provides information on current valid roadwork and associated constraints. | **Long term roadworks information**: signalling information such as **forbidden overtaking, forbidden access to special vehicle categories, alternative routes, topological information about modified road layouts** | Day 2 |

[46] CAR 2 CAR Communication Consortium (2019): Guidance for day 2 and beyond roadmap.https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_WP_2072_RoadmapDay2AndBeyond.pdf

| | | | |
|---|---|---|---|
| **Support for (semi) automated functions** | The infrastructure will support single vehicles and vehicles in Cooperative Adaptive Cruise Control (CACC) strings or platoons with information about applicable regulations which are specific to one or more automation levels. | Information may include **clearance information for a certain section to automated driving**, as well as minimum, maximum or recommended **speed**, and minimum and recommended **inter-vehicle distance**, per automation level. | Day 2 |
| **Vulnerable Road User Protection** | Provides warning to vehicles of the presence of vulnerable road users, e.g., pedestrian or cyclist, in case of dangerous situation. | For day 2, vehicles and **infrastructure can share information about pedestrians or cyclists detected via local sensors**, and let receiving vehicles detect the occurrence of risky situations associated to Vulnerable Road Users (VRU) presence. | Day 2 |
| **Cooperative ACC** | C-ACC is based on V2X to obtain lead vehicle dynamics and general traffic ahead in order to enhance the performances of current ACC. | The infrastructure can play a role in **suggesting the speed to be adopted in CACC mode as well as the point from where CACC is allowed** | Day 2 |
| **Co-operative merging assistance** | CAVs involved in a merging negotiate together the merging process to avoid collision. | The road infrastructure can in special case participate in the **coordination process of merging**. | Day 3+ |
| **Cooperative lane change** | CAVs involved in a lane change negotiate together the manoeuvring process to avoid collision. | The road infrastructure can in special case participate in the **coordination process of lane change**. | Day 3+ |
| **Cooperative Transition of Control** | CAVs can cooperate in organizing a transition of control such that minimizes the risks. | Road infrastructure could suggest **time or space where to safely trigger a Transition of Control** (ToC) | Day 3+ |
| **Cooperative manoeuvre** | Manage CAVS or a platoon of CAVs at signalised intersections, e.g. (I2V) interactions for optimal coordination of vehicle transit at cooperative intersections (CIs). CAVs and CIs interact by executing a negotiation process in which speed change advisory and lane change advisory are provided | CAVs communicate their planned intentions to the infrastructure and **infrastructure provides feedbacks on the compliance of the advised speeds or lane changes** | Day 3+ |
| **Manoeuvre Coordination (e.g. in roadworks area)** | Manoeuvre Coordination Service (MCS) is based on V2V interactions, but infrastructure may have a role e.g. in roadworks situations. | **infrastructure can provide suggestions (e.g. lane change advices or speed advices**) to the CAVs | Day 3+ |
| **Automated GLOSA / Automated GLOSA with negotiation** | Extends the Green Light Optimum Speed Advisory (GLOSA) by implementing automated functions for adaptation to the speed suggested by the infrastructure or computed by the vehicle. | CAVs and/or CAVs strings communicate if the GLOSA advices can be executed by updating their own transmitted messages. This **feedback can be used by the traffic light controller to further refine the traffic light phase and time algorithms** | Day 3+ |

### 3.2.2. THE 5GAA ROADMAP

The **5G Automotive Association (5GAA)** views a future in which a combination of connected and automated vehicles co-exist with vehicles that are not enabled by automated driving functions. Connectivity will according to them support automation while bringing benefits to what they call mixed traffic situations in which some use cases on the road are enabled into becoming automated.[47] The 5GAA sees the next generation of connected mobility, automated vehicle and intelligent transport solutions as based on C-V2X (2019).

The 5GAA outlines the following probable development and timeline.

- In the next two to three years 5GAA expects to see mass deployment of traffic efficiency and basic safety V2X use cases around the world
- From 2024 onwards they anticipate a large-scale introduction of advanced safety and automated driving use cases supported by C-V2X
- Additional connected automated driving functionalities are expected to be introduced starting in 2026
- From 2022 onwards, advanced use cases such as Hazard Information Sharing for Automated Vehicles (AVs) and HD Map Sharing for AVs will further develop automated driving
- By 2025/26, use cases will be extended to operate on public roads and in parking garages, leveraging 5G-V2X
- All new AD vehicles will be equipped with 5G-V2X from 2026
- Enhanced urban and highway pilots are expected to start in 2029 in dedicated areas allowing Dynamic Cooperative Traffic Flow and Dynamic Intersection Management

According to the **5GAA**'s roadmap the C-ITS deployment (until 2024) focuses on traffic efficiency and basic safety V2X use cases around the world. This can be called an initial step (Step I is not included in this study). From 2024 onwards, 5GAA anticipates an introduction of advanced safety and automated driving use cases. In the second step (Step II) cooperative manoeuvres and HD sensor sharing partly reinforced by road operators or authorities will support automated driving e.g., with "cooperative perception".

[47] 5G Automotive Association (5GAA), "A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs – 5G Automotive Association.", September 2020, https://5gaa.org/news/the-new-c-v2x-roadmap-for-automotive-connectivity/

Finally, (Step III) involves more dynamic cooperative automated driving being enabled with the support of road operators, at selected hotspots (e.g., intersections).[48]

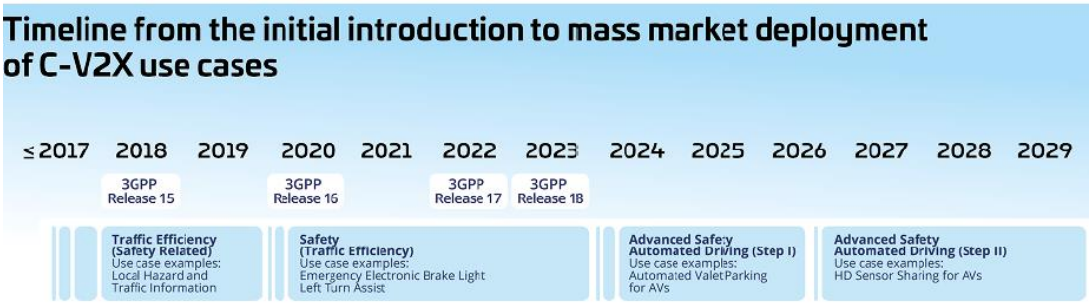



**Figure 8. 5GAA timeline of mass market deployment of C-V2X Use cases Source: 5GAA, 2020**

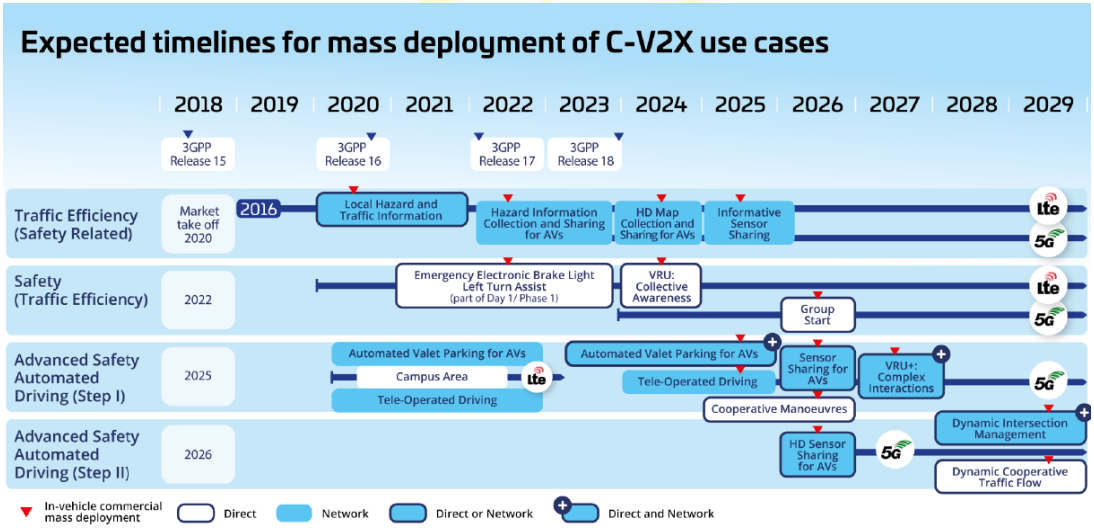



**Figure 9. 5GAA timeline of mass market deployment of C-V2X Use cases. Source: 5GAA, 2021**

[48] 5GAA "Use Case Implementation Description (UCID)", 2021 https://5gaa.org/wp-content/uploads/2021/04/use-case-t21001.pdf

The following table lists future (step II and III) use cases, which are relevant from a road operators perspective, as defined in three of the 5GAA's roadmap documents.[49] [50] [51]

The table below provides use case name, description, role or data provided by infrastructure (usually managed by the road operator or authority), and the step defined in the source documents.

**Table 3 Future C-ITS use cases according to the 5GAA**

| Use Case | Description | Role of (or data provided by) Infrastructure | Step |
|---|---|---|---|
| **Real-Time Situational Awareness and High-Definition Maps: Hazardous Location Warning** | A host vehicle is made aware of accidents, traffic, adverse weather, road conditions, construction and other situations detected and shared by remote vehicles (or by Traffic Management: real-time HD map update) | Traffic management collects accidents, traffic, adverse weather, road conditions, construction and other situations and reports them to other vehicles (**real-time HD map update**) | II |
| **Cross-Traffic Left-Turn Assist (LTA)** | Alerts Host Vehicle (HV) attempting to turn left across traffic of a Remote Vehicle (RV) approaching from the opposite direction in the lanes that HV needs to cross | Provide (if available) **Lane designations and geometry, Intersection geometry, Traffic light signal phase and timing and Current road conditions** (if available).<br><br>In case of LTA coordinated by road authority/road operator, it is assumed that the roadside infrastructure at the intersection has **real-time traffic data collection and reporting capabilities and that the backend system algorithms can achieve target detection, positioning, and tracking**. | II |
| **Intersection Movement Assist** | Stationary HV proceeds straight from stop at an intersection. HV is alerted if it is unsafe to proceed through the intersection about:<br>o Approaching cross-traffic from the left<br>Approaching cross-traffic from the right | Provide (if available) **Lane designations and geometry, Intersection geometry, Traffic light signal phase and timing and Current road conditions** (if available). | II |

[49] 5GAA, "C-V2X Use Cases and Service Level Requirements Volume I", 2020. https://5gaa.org/wp-content/uploads/2020/12/5GAA_T-200111_TR_C-V2X_Use_Cases_and_Service_Level_Requirements_Vol_I-V3.pdf

[50] 5GAA, "C-V2X Use Cases Volume II: Examples and Service Level Requirements", 2020 https://5gaa.org/wp-content/uploads/2020/10/5GAA_White-Paper_C-V2X-Use-Cases-Volume-II.pdf

[51] 5GAA, "Use Case Implementation Description (UCID)", 2021. https://5gaa.org/wp-content/uploads/2021/04/use-case-t21001.pdf

| | | | |
|---|---|---|---|
| | o Oncoming traffic intending to turn left | | |
| **Vulnerable Road User** | Alert Host Vehicle (HV) of approaching VRU in the road or crossing an intersection and warn of any risk of collision | In case of limited Line of Sight (LoS), **VRUs can be detected via infrastructure support and warning notifications are shared with drivers**, for example via: Roadside units | II |
| **Infrastructure Assisted Environment Perception** | When an automated vehicle enters a section of the road that is covered by infrastructure sensors it subscribes to receive information from the infrastructure containing environment data from dynamic and static objects on the road. This data is used to increase the trust level of the cars own sensor observations and extends its viewing range. | The road **infrastructure provides the sensor infrastructure, data, and processing capabilities to perform sensor data fusion, calculate individual trajectories, and store and communicate the results in real time**. Infrastructure sensors may include radars, cameras and/or LiDARs, which may object lists or raw data (e.g. compressed video stream). Object lists can contain dynamic information about speed and direction. | II |
| **Obstructed View Assist** | HV is provided an alternate when faced with an obstructed view | **Surveillance cameras provide alternate views (and camera's location and vector)** if available | II |
| **Group Start** | A traffic control centre or HV identifies several vehicles which intend to cross an intersection on a similar path at a similar time. The candidate vehicles are placed into groups following the same paths, guided through the intersection by their corresponding 'group lead' vehicle. After the manoeuvre is executed the groups are dissolved. The lead vehicle reports the manoeuvre to the traffic control centre. | The **traffic control centre provides tactical and strategic information to facilitate the group start activity**. This happens while the vehicles are approaching the intersection and while vehicles are waiting at the red light. The **traffic control centre assigns the leadership role to leading vehicles in the group and announces the final group properties (e.g. planned manoeuvre and trajectory**, including acceleration, yaw rate, etc.) Traffic light sends signal phase and timing information to the traffic control centre and/or to all vehicles in the vicinity | II |
| **Infrastructure-Based Tele-Operated Driving** | Infrastructure (e.g., sensors, cameras) support the remote driver by providing a real-time picture of the road environment centred around the HV. Based on the perceived situation and the capabilities of the car, the remote driver can provide the appropriate trajectory and manoeuvre instructions to help the autonomous vehicle move to a safer location. | The road **infrastructure provides the sensor infrastructure, data and processing capabilities to perform sensor data fusion and communicates the results in real time**. Infrastructure sensors may include radars, cameras and/or LiDARs, which may object lists or raw data (e.g., compressed video stream). | II |

| | | | |
|---|---|---|---|
| **Continuous Traffic Flow via Green Lights Coordination** | A series of traffic lights (usually three or more) are dynamically coordinated to allow continuous traffic flow over several intersections in one main direction. | The **HV reports location, direction and/or intended trajectory to a traffic management server or to roadside infrastructure. HV receives timing and/or speed recommendations either by a traffic management server or by roadside infrastructure** in order to follow the cascade of green lights. | III |
| **Automated Intersection Crossing** | An autonomous vehicle goes through an intersection with a set of traffic lights AV goes through or stops taking signal timing into account. When stopping at the intersection, the AV can readjust its position. | **Traffic lights (intersection manager) control traffic flow at intersections. The intersection manager sends to the HV the roads, lane designations, geometry and the phase and timing of traffic lights at the intersection** | III |
| **Autonomous Vehicle Disengagement Report** | When an autonomous HV virtual driver system disengages, it submits a disengagement report containing a time-windowed recording of vehicle systems data, rich sensory information and dynamic environmental conditions to OEM and government data centres. | Nearby actors (including **infrastructure) capture relevant data and send it to the HV such as relevant surveillance cameras capture a time-windowed recording. Traffic signals capture timing and phase information** | III |

### 3.2.3. THE ERTRAC ROADMAP

According to the **European Road Transport Research Advisory Council, ERTRAC** Day 1 C-ITS services are today ready for deployment since implementations and tests of such services have been made throughout Europe and have been harmonized in the C-ROADS initiative, complementing the CAR 2 CAR Communication Consortium's (C2C-CC) "Basic System Profile" which defines message profiles for vehicle-based C-ITS messages. Efforts that are viewed according to ERTRAC as major contributors towards a harmonized Day 1 C-ITS deployment in Europe. A progressive stepwise increase of automation levels will be seen according to ERTRAC during the upcoming decade in which by 2050 vehicles should be electrified, automated and shared (ERTRAC, 2019).

One of the key features of the Connected and Automated Driving Roadmap are development paths. Since the 2019 roadmap update has paid particular attention to Level 4 of Automated Driving according to SAE J 3016 the corresponding use cases are highlighted with a red box.

- Targeted Level 4 passenger car use cases which will reach maturity for deployment in this decade (2021-2030) comprise Highway Autopilot including Highway Convoy as well as Urban and Suburban Pilot.

- Corresponding freight vehicles use cases comprise of Highly Automated Vehicles in confined areas, followed by the Operational design domain (ODD) extension towards Hub-to-Hub operation and finally operation on open roads.

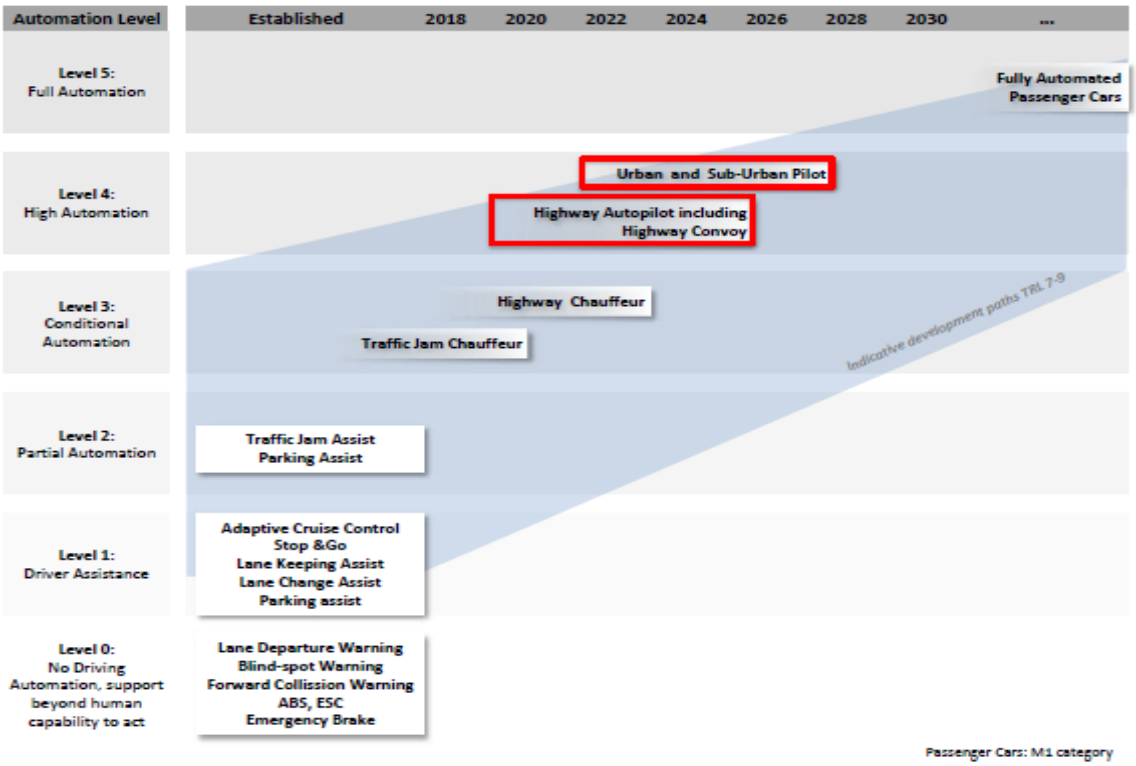



**Figure 10 The Automated Driving development path for passenger cars (ERTRAC 2019)**

European ITS Platform

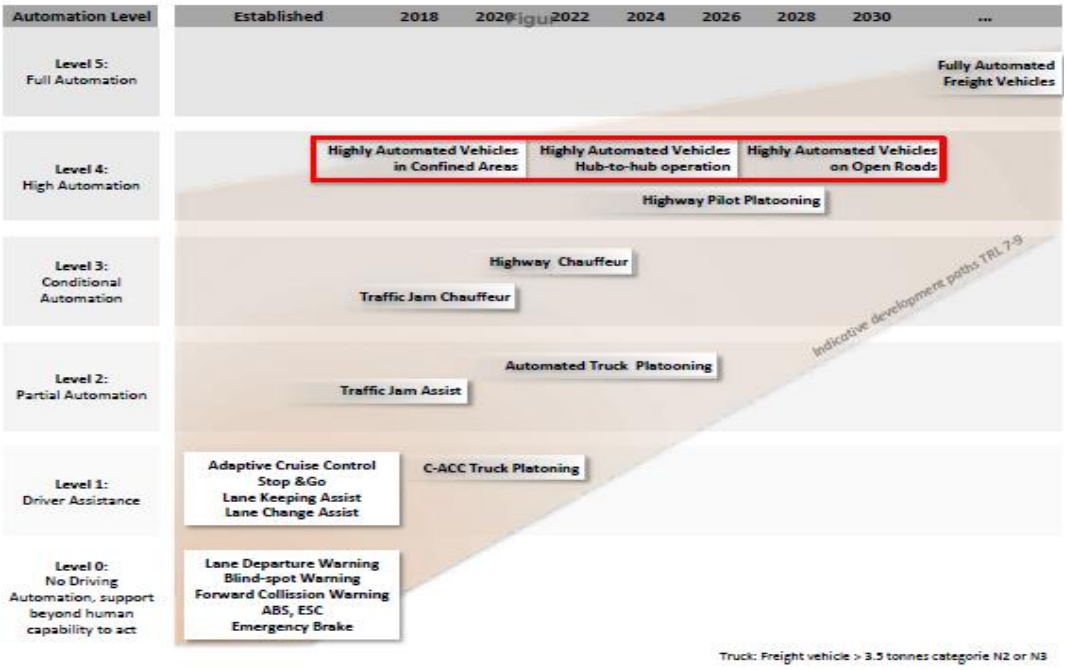



**Figure 11 The Automated Driving development path for freight vehicles (ERTRAC 2019)**

The 2021 update of the roadmap takes into account that C-ITS has been deployed in vehicles (serial vehicles) and road infrastructure (regular operation). It will do so by embedding the cooperative C between the elements of connectivity and automation (CCAD Roadmap). Or to put it alternatively, the roadmap puts more emphasis on both connectivity and cooperation as enablers for automation. Although the update is still work in progress, the presentation held at the ERTRAC Annual Conference (2nd July 2021) already sheds some light on the important argumentation lines of the new roadmap.[52]

- The basic approach is to provide a longer term vision of Connected Cooperative and Automated Driving, pointing towards the mid century (Vision 2050). This vision is complemented by the Agenda 2030, embracing what needs to be done in this decade of intensified co-creation, mostly on topics related to research and innovation. The view falls is in line with a vision in which the CCAM Partnership (of approximately 50 co-programmed partnerships within the Horizon Europe) is active. The years between 2030 and 2040 – the decade of maturity – are the years where CCAM services are envisioned to bring larger benefits to citizens and society in general (cf. the Outlook 2040 reference in the roadmap).

[52] Graeter, A., Steiger, E., Harrer, M., Rosenquist, M., "Connected Cooperative and Automated Driving" Update of the ERTRAC Roadmap, 2nd July 2021, www.ertrac.org, accessed 2021-08-04.

- Automation today takes charge or advances from different angles. On the one hand it represents the evolution from driver assistance systems to higher automation levels on a preferably large and uninterrupted Operational Design Domain (ODD). On the other hand even higher automation can be demonstrated and operated already by today but tied to confined areas or restricted operational domains. This duality is characteristic for the present state of development and will most likely remain throughout this decade.[53] Automation will develop in different domains (e.g., confined areas, parts of the urban network, corridors on the high-level road network) within a large variety of use cases. Only in the decade of maturity will the use cases widen up and potentially converge. Also, the domains will grow together and cover not only much of the corridors but also most of the highway network. In the urban environment they will grow out of confined areas into full urban autonomy shuttle and delivery services. Lastly but not least, specific parts of the rural network will be accessible for CCAM services to bring rural autonomy to settlements.
- The roadmap makes use of domain canvasses in order to map **enablers** (grey boxes in the figure below) with related **use cases** (centre yellow box). An example for the domain canvas titled "Assisted Corridors/Highways 2030" is shown below.

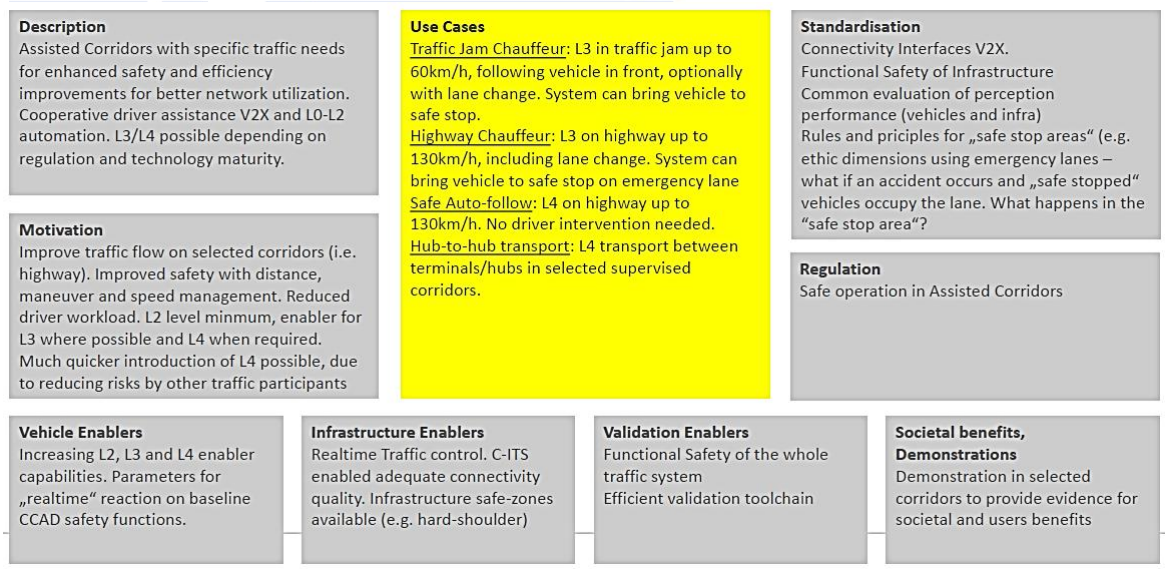



**Figure 12 Example domain canvas Assisted Corridors/Highways 2030**
**Source: ERTRAC, 2021**

[53] Bryant Walker Smith, "How Governments Can Promote Automated Driving", 47 N.M. L. Rev. 99 (2017), Available at SSRN: https://ssrn.com/abstract=2749375 or http://dx.doi.org/10.2139/ssrn.2749375, accessed 2021-08-05.

## 3.3. The Euro NCAP roadmap

The non-profit **European New Car Assessment Program (Euro NCAP)** could play an important role in promoting the C-ITS capabilities of new vehicles. The program applies an assessment scheme which is continuously developed which delivers a safety rating (star rating) of cars approaching market introduction. In doing so Euro NCAP aids both sides of the market, consumers as well as OEMs (and their supply chain):

- The program provides "signalling" to consumers about the safety rating according to the Euro NCAP assessment scheme and test protocols. As a consequence, it reduces quality uncertainty for consumers who now can rely on the test results.
- It also stabilises expectations for OEMs on future paths towards even safer road traffic (in pursuit of Vision Zero). The Euro NCAP roadmaps (mid-term) and the assessment schemes (shorter term) provide incentives to OEMs to channel their efforts and investments to even safer products.

In terms of roadmap guidance, the Euro NCAP Roadmap 2025 lists V2X communication as a milestone for 2024.[54]

In the context of what has been presented above, the Euro NCAP Advanced Reward for the C-ITS based Local Hazard Warning[55] represents a milestone in the recognition of C-ITS. In

## 3.4. The CCAM Platform

It is apparent that C-ITS is becoming increasingly relevant within the field of Connected, Cooperative and Automated Mobility (CCAM). The European Commission has stressed the importance of C-ITS when developing the CCAM approach. In terms of strategy, the cooperative "C" which has been instrumental for the C-ITS strategy (2016) is now a key part of the CCAM approach which has led to the establishment of the CCAM Platform as a COM Expert Group (2019) and more recently as embedded into the Sustainable and Smart Mobility Strategy (2020).[56] The illustration below brings the essence of the relevant strategy parts into a roadmap-like illustration.[57]

[54] https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf

[55] "Volkswagen Safety Technology Rewarded by Euro NCAP", March 2020, https://www.euroncap.com/en/press-media/press-releases/volkswagen-safety-technology-rewarded-by-euro-ncap/, accessed 2021-08-06.

[56] European Commission, "Sustainable and Smart Mobility Strategy – putting European transport on track for the future, COM (2020) 789 final", Brussels 9.12,2020.

[57] Van der Linden, G., "Sustainable and Smart Mobility Strategy – How Road Infrastructure can support Automated Driving", EU CAD Conference 2021, https://www.connectedautomateddriving.eu/eucad2021/, accessed 2021-08-06.

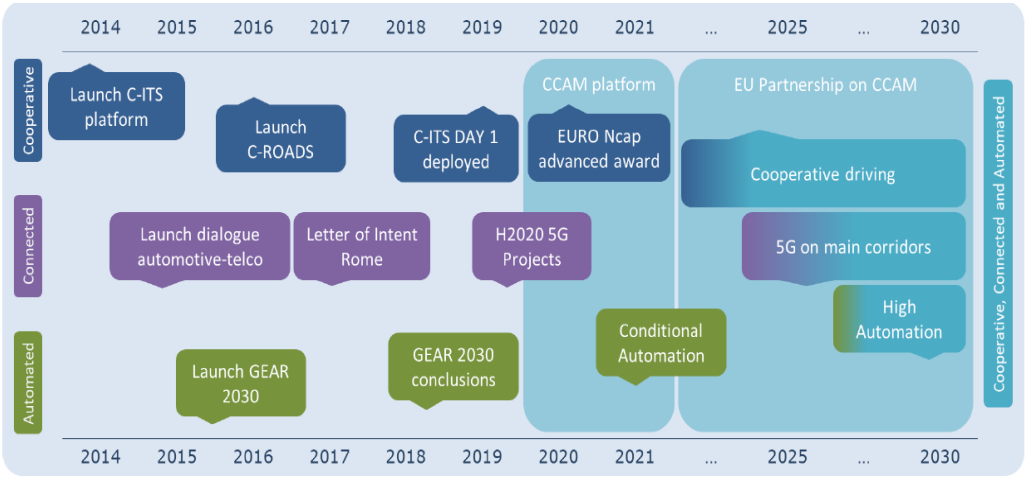



**Figure 13 CCAM in the context of the Sustainable and Smart Mobility Strategy (Van der Linden 2021)**

- CCAM refers to the convergence of the three streams (Connectivity, Cooperation, Automation), as illustrated by the Declaration of Amsterdam, and links it to specific COM actions that aid and facilitate the development towards CCAM.
- It highlights the importance of the Horizon Europe CCAM Partnership for the convergence of the streams, i.e., to come to real cooperative driving (manoeuvres), to roll out 5G along main transport corridors and to advance from current pilots on Level 3 Automated Driving to mature High Automation.

EU EIP
European ITS Platform

# 4. Setting a Strategy – Roadmap beyond initial deployment

In order to provide benefits of C-ITS to all stakeholders it becomes apparent that a stakeholder specific profile concerning roles and responsibilities is needed. Road administrators will need to be informed not only about their own potential roles and responsibilities for the implementation of intended services but also in terms of a harmonisation between different stakeholders covering the interfaces and overlapping areas of interest (Tool & Verweij, 2017).[58]

It can be expected that a move from one deployment phase to the next one takes at least five years which is more or less congruent to the necessary time for the revision and the development of new standards, including lee time for preparation as well as profiling and testing.

| Lifecycle phases<br>Collaboration platforms (ex.)<br>Generation | Pre-Development (R&I) | Pilots and (Pre-)Deployment | Regular Operation |
|---|---|---|---|
| ITS | [past] | [past] | |
| C-ITS | [past] | C-ROADS | [C-Roads operation] |
| CCAM | CCAM | [n.a.] | [n.a.] |

**Figure 14 Collaboration for harmonised development and deployment Source: Torsten Geissler, Sandro Berndt-Tolzmann, Holger Drees, Farzin Godarzi, 2021**

The deployment of C-ITS faces many important issues still unresolved, such as legal, organisational, administrative, governing, technical and standardisation issues as well as implementation and procurement issues addressing those found in the Day 1 and the Day 1.5 services. Interoperability will be key for a successful introduction of C-ITS systems and services. In this context establishing standards are one essential tool to achieve interoperability, but standards alone are not sufficient to ensure interoperability. A shared understanding and consistent interpretation of applications and useful standards is necessary to provide benefits to all C-ITS relevant stakeholders.

[58] Onno Tool and Fred Verweij, "(CODECS) Deliverable 4.1 Update Website Report on State - of - the - Art Strategy for C-ITS Deployment," 2017, http://www.codecs-project.eu/index.php?id=32.

Communication technologies and strategies for C-ITS still bring forth uncertainty for whether there is a need for special roadside equipment for C-ITS. Related questions become who is responsible for the installation and maintenance of the roadside equipment, the importance of V2I and V2V communication, associated costs, and what dialogue or not exists with OEM's regarding what C-ITS technology they will equip in their vehicles and when.

Successful C-ITS deployment will most likely require that listed Day 1 and Day 1.5 services and applications deliver value to customers. These services and applications will need their own set of roll-out plans linked to specific roles and responsibilities for their implementation and management and business plans. It is expected that new technologies will emerge on a regular basis but applied as C-ITS applications they need to be based on standardised sets for communication and validated in relevant field operation tests. While Day 1 and 1.5 services and applications are not directly linked to a specific communication technology or solution, they may as such require specific technologies and communications solutions to function optimally.

Finally, the deployment of C-ITS and the development of a successful eco-system will need to take into account emerging ITS developments that can be matched to a consistent set of profiles that take into account new parameters into what could be named a form of "C-ITS release version 2".[59] Even if there might be a hesitancy to deploy C-ITS, due to having two potential C-ITS communication technologies available at the moment such as ITS-G5 and Cellular V2X, the road operators should still start deploying C-ITS solutions. Investments related to data collection, management, or processing of C-ITS messages will not be wasted even if one would "bet on" the "wrong" C-ITS communication technology since the upper layers of the stack is the same for both technologies. The same data can most likely be used in the future regardless of the technology selected. Supporting this statement is the following quote from the communications technology company Qualcomm (2019):

> "The automotive industry…have done considerable work in defining the Applications, the message/facilities later, security services and the Transport/networking layers. C-V2X leverages all of the existing standards in these layers, and just replaces the PHY and the MAC (commonly called the Access layers) from 3GPP." [60]

One issue although, that is still unclear and needs to be addressed, is how different short range technologies can coexist in the 5.9 GHz frequency band.

[59] https://www.itsstandards.eu/app/uploads/sites/14/2020/10/C-ITS-Brochure-2020-FINAL.pdf
[60] https://www.qualcomm.com/media/documents/files/c-v2x-its-stack.pdf

## 4.1. C-Roads operation in 2023

C-Roads and its Service Catalogue of use cases could be an example of a service implementation beyond deployment (e.g., a C-Roads catalogue 2.0). With it you will advance on services that have already been tested and in some circumstances already deployed (e.g., a next version of Road Works warning). Current pilots within C-Roads which are running until 2023 and that go beyond Day 2+ use cases need to address pertinent ecosystem issues  for a fully operational C-ITS delivery, which incidentally is the title of a report which is currently under development in the C-Roads Platform WG 1 on Organizational Issues. C-Roads provides a Service Catalogue which is expanded by new releases twice a year. The development will most likely need the following building blocks in order for it to advance (see the figure below).

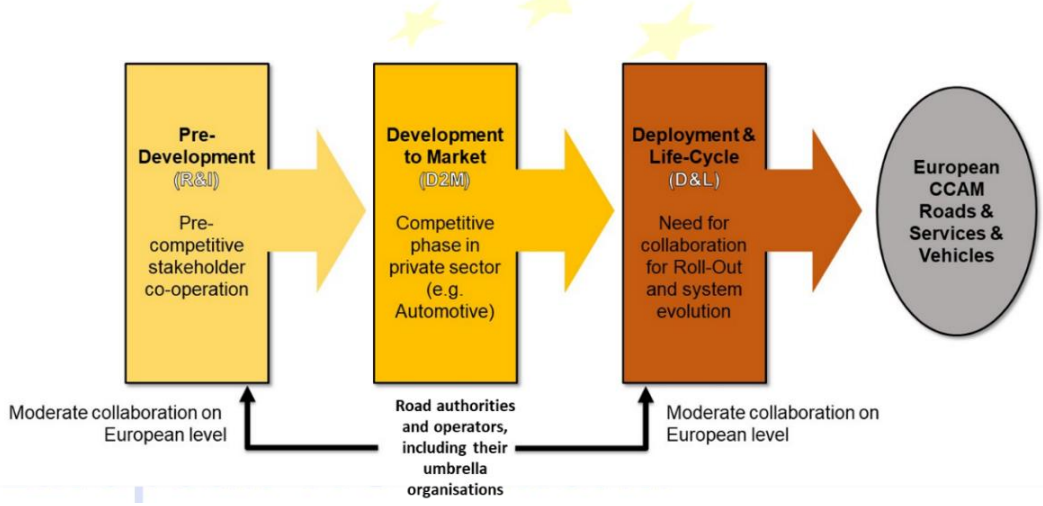



**Figure 15 Cooperation in technology Source: CEDR CAD (2020), including minor adaptations by Torsten Geissler, Sandro Berndt-Tolzmann, Holger Drees, Farzin Godarzi, 2021**

The C-Roads catalogue contains services and use cases that have been specified, tested and verified. C-Roads encourages deployment of harmonised C-ITS services but does not put obligations on its members to deploy any particular services and use cases thereunder. The interoperability principle however requires for when a service/use case will be deployed that it will be done in line with the agreed specifications and documents which accompany the C-Roads releases.

It is expected that the C-Roads catalogue will expand in the future along two dimensions:

- **More C-ITS services will be verified.** Verified services today match the list of Day 1 services and Day 1.5 services which are the first C-ITS services with infrastructure involvement. These services provide information and warnings only. It is expected that services for Day 2 and beyond (Day 2+) will expand along the cooperation classes indicated by the SAE (cf. SAE J 3216) from “status sharing over intent sharing” to “agreement seeking and prescriptive (actions)”. A near term development into this direction would be a C-ITS service on automated vehicle guidance. When C-ITS services help fulfil driving tasks beyond sensing (i.e., plan and act) the issue of functional safety comes into play which needs to be addressed. The information on reliability, which is or could be a safety qualifier in terms of meeting functional safety requirements, would be an essential component in extending operational Design Domains of automated vehicles.
- **Each C-ITS service will cover more and more use cases.** A service will be more detailed in functional terms. For example, a road works warning service communicating amid others lane closures. How long term road works warnings can be communicated – by making use of, or by combining, different message types – is still being discussed (and has been for quite some time) in the community.[61] It has not evolved yet to a harmonised specification.

By nature, the C-Roads service catalogue has a short to medium time span in being developed. The timespan is predefined by the process of coming up with harmonized and tested specifications. From proposing new services and/or new use cases developing into harmonized specifications with aligned views on how to provide the service lasts one to one and a half years. In addition, the test cycle involves developing test protocols, exchanging PCAP (packet capture) files, and verifying interoperability which all adds up to the overall process requiring two to three more years of lee time.

Some more specific issues are related to the transition of pilot deployment to full-scale deployment and integration of C-ITS services into day-to-day operation. Processes will need to define, to just name a few of them, issues such as how to implement changes to the specifications aligned across sectors (such as automotive-road infrastructure), how to provide a first line of help to users of C-ITS services, how to monitor operations or how to monitor the performance of services. C-Roads has provided a report concerning an operational ecosystem for C-ITS service delivery from a road infrastructure point of view which lists the necessary processes and provides a perspective towards possible governance structures for multi-actor collaboration without a regulatory anchor.

[61] Volny, M., Message architecture beyond initial deployment phase, in: Drees, H. et al., Webinar Documentation – Profiles: Lessons Learned and Perspectives, CODECS Deliverable D2.5, 2018, pp. 21-24.

## 4.2. Developments towards CCAM in 2025 and beyond

Within the area of CCAM there has been a shift in focus in which the cooperate aspect is now a secondary priority instead of a first priority. The figure below demonstrates how increasing CCAM performance will most likely progress.

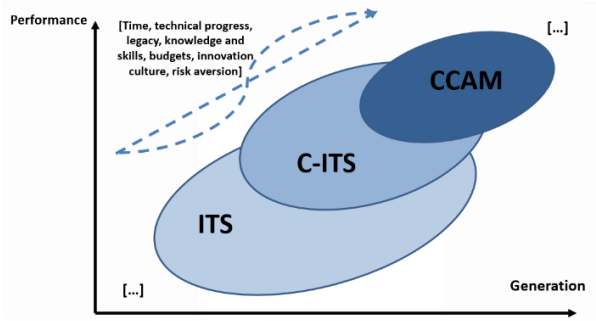



**Figure 16 Road authority/operator technology generations Source: Adapted from Sundberg (2012) by Torsten Geissler, Sandro Berndt-Tolzmann, Holger Drees, Farzin Godarzi, 2021**

Based on the longer term views seen in the industry roadmaps presented earlier (e.g., C2C-CC and the 5GAA) in which road authorities and operators have proactively contributed or commented it is apparent that the road authority's technology development will most likely become increasingly connected to the development both of Connected automated driving (CAD) and CCAM.

ERTRAC as an example is already pointing towards a need for aligning connected and automated driving (CAD) with the deployment of C-ITS and in balance with 5G deployment. The connectivity aspects of CAD will according to ERTRAC be crucial for higher automation levels, in which connectivity and cooperative systems are important enablers for higher levels of automation (2019). A major factor they point out is the increase of 5G networks since it may allow connectivity patterns that go beyond what is possible today (ERTRAC, 2019).

## 4.3. Ways forward?

A way forward will most likely encompass the following.

- A continued deployment of C-ITS Day 1 and Day 1.5 services advancing to more sophisticated services of relevance also within a CCAM context. Most likely going from providing "information only" to executing actions in vehicles using hybrid C-ITS

technology (short and long range) which has been tested, proven and worked out by C-Roads via the Hybrid Communication Task Force (WG 2 TF 4).

- Taking advantage of the potential provided by in-vehicle data for SRTI as demonstrated in the Proof-of-Concept of the Data Task Force, now the Data for Road Safety (DFRS) ecosystem.
- Gaining more insight into the set-up of notifications, which has been gathered via pilots and similar developments, most likely in terms of how to achieve more uniformity, which in turn increases usability. Including insights which can make possible better filtering based on for example geographical locations, or facilities, permitting cross checks with notifications from other vehicles.
- Opening up and being ready for new stakeholders joining the ecosystem in which all partners are positive about the ecosystem while indicating that it is desirable for more partners to join. The advice here is to actively invite new partners to do so. Member States can support this by actively recruiting new partners.
- Striving for more OEMs and service providers to join the ecosystem. More data will become available as a result, resulting in greater coverage of possible notifications and more reliable information.
- Expanding the amount of data types of SRTI messages. At present, only a limited number of SRTI messages are shared per party. It is recommended that further discussions be held with these parties regarding an expansion of SRTI messages.[62]
- Continuing the development of standards. All vehicle manufacturers are currently developing the data infrastructure required for large-scale rollouts of data sharing.
- Testing the possibility to take advantage of C-V2X technology (LTE-V2X and 5G-NR) in order to deliver C-ITS services that are capable of taking up related data, (provided that the short-range technologies can co-exist in the 5.9 GHz band). This is under study by the Commission.
- Experimenting with "hybrid" roadside units that can listen to various communication technologies at once, such as ETSI ITS G5 and Cellular-V2X.

## 4.4. Recommendations

To conclude this chapter, road authorities, and road operators such as those contributing to the European C-Roads platform would benefit from keeping in mind the following principal and more immediately necessary pointers which are supported by other studies.

[62] EU commission *Delegated Regulation (EU) No 886/2013 of 15 May 2013* supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users Text with EEA relevance. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32013R0886 accessed 2021-10-11.

- **Keep in mind backwards compatibility. "**Backwards compatibility" is needed in which new C-ITS equipment beyond Day-1 services and applications, such as those developed for Day 1.5 or even Day 2 services, need to support and safeguard already deployed C-ITS services.
- **Be open towards hybrid solutions.** Consider that the evolution of cellular communication standards towards 5G is expected to bring further improvements to long range cellular communication (such as coverage improvements and signalling efficiency), which will provide benefits to the hybrid communication approach while complementing short range connectivity. The C-Roads Platform as an example supports the use of hybrid communication technologies.
- **Keep in mind cybersecurity**. Much of the common platforms environed for the deployment of C-ITS solutions are based on the Cloud concept. Cloud solutions and their technologies need to support secure connections and be based on strategies for achieving interoperability between all stakeholders.

# 5. References


3rd Generation Partnership Project (3GPP),” Release 15 Description; Summary of Rel-15 Work Items”, 2019.
https://www.3gpp.org/release-15

5G Automotive Association (5GAA), “5GAA Initial C-V2X System Profile (ICSP) – Amendments to C-ROADS Roadside System Profile,” 2018.

– “A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs – 5G Automotive Association,” 2020.
http://5gaa.org/news/the-new-c-v2x-roadmap-for-automotive-connectivity

– “C-V2X Use Cases and Service Level Requirements Volume I”, 2020
https://5gaa.org/wp-content/uploads/2020/12/5GAA_T-200111_TR_C-V2X_Use_Cases_and_Service_Level_Requirements_Vol_I-V3.pdf,

– “C-V2X Use Cases Volume II: Examples and Service Level Requirements”, 2020.
https://5gaa.org/wp-content/uploads/2020/10/5GAA_White-Paper_C-V2X-Use-Cases-Volume-II.pdf,

– “Use Case Implementation Description (UCID)”, 2021.
https://5gaa.org/wp-content/uploads/2021/04/use-case-t21001.pdf,

Amsterdam Group, “Road Map,” Amsterdam Group, 2013.
http://amsterdamgroup.mett.nl/Road+Map/default.aspx

Amelink, M. *et al.,* ”Road map and action to facilitate automated driving on TEN road network – version 2020, Deliverable Task 3 of EU EIP”, 2020.

Berndt, S., *et al*., “C-ITS Deployment Preparation for road authorities and operators, Deliverable 2 of EIP+ Activity 4.1”, 2016.

Carreras, A., Daura, X., Erhart, J., Ruehrup, S., ”Road infrastructure support levels for automated driving, EU-TP 1488”, 25th ITS World Congress, Copenhagen, 2018.

C-Roads ”C-Roads, With C-ITS towards safer roads in Europe”, Press release 2021-06-04.
https://www.c-roads.eu

– “Press Release: ASFINAG Connects Roads with Vehicles on a Large Scale in Europe: C-Roads,” 2020.
https://www.c-roads.eu/platform/about/news/News

– ”The C-Roads Platform, An overview of harmonised C-ITS deployment in Europe”, 2021.
https://www.c-roads.eu/platform/documents.html

CAR 2 CAR Communication Consortium, “C-ITS Deployment Takes off, Increasing Road Safety and Decreasing Congestion.” Press release October 2019.

– “Guidance for Day 2 and beyond Roadmap”, 2019.
https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_WP_2072_RoadmapDay2AndBeyond.pdf

– “Guidance for Day 2 and beyond Roadmap v.1.2”, 2021.
https://www.car-2-car.org/news-events/news/detailview/the-car-2-car-communication-consortium-published-a-new-white-book-on-the-12th-of-july-2021-110/

Dopart, K., U.S. DOT ”Cooperative Driving Automation Research”, SIP-adus Workshop, 2020.
https://www.sip-adus.go.jp/evt/workshop2020/file/cv/07CV_04_Dopart.pdf

European Commission, “A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility”, 2017.
https://ec.europa.eu/transport/themes/its/c-its_en

– “Horizon Europe – The next generation of European Partnerships, Factsheet”, 2021.

– ”Sustainable and Smart Mobility Strategy – putting European transport on track for the future,

EC COM (2020) 789 final", Brussels, 2020-12-09.

ERTRAC (European Road Transport Research Advisory Council), "Connected Automated Driving Roadmap", 2019.

– "Connected, Cooperative and Automated Mobility Roadmap: Draft version 9", 2021.

Euro NCAP, "Euro NCAP Roadmap 2025," 2018.
https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf

– "Volkswagen Safety Technology Rewarded by Euro NCAP", March 2020,
https://www.euroncap.com/en/press-media/press-releases/

Federal Communications Commission (FCC) "FCC Modernizes 5.9 GHz Band to Improve Wi-Fi and Automotive Safety", 2020
https://www.fcc.gov/document/fcc-modernizes-59-ghz-band-improve-wi-fi-and-automotive-safety

Flensholt, J. *et al.,* "NordicWay Service Definitions – Services and Use Cases", 2020

García, A., F. J. Camacho and P. Padovani, "Examining the effect of road horizontal alignment on the speed of semi-automated vehicles", Accident Analysis & Prevention, Vol. 146 (2020), 2020.

Gasser, T., Frey, A., Seeck, A., Auerswald, R., "Comprehensive Definitions for Automated Driving and ADAS", Paper 17-0380, Proceedings of 25th ESV Conference in Detroit, 2017.
https://www-esv.nhtsa.dot.gov/Proceedings/25/25ESV-000380.pdf

Graeter, A., Steiger, E., Harrer, M., Rosenquist, M., "Connected Cooperative and Automated Driving" Update of the ERTRAC Roadmap, 2021-07-02.

GSM Association, "Spectrum for Intelligent Transport Systems – GSMA Public Policy Position", 2017.
https://www.gsma.com/spectrum/wp-content/uploads/2018/12/

Hendriks, L., van Heijningen, H., Jorna, R., "Leading Innovation Timeline as an enabler for Traffic Management Roadmaps", Transportation Association of Canada and ITS Canada 2019 Joint Conference and Exhibition, 2019.
https://www.tac-atc.ca/sites/default/files/conf_papers/

ISO, "Cooperative intelligent transport systems (C-ITS) Guidelines on the usage of standards Edition 26. June 2020", 2020.
https://www.itsstandards.eu/app/uploads/sites/14/2020/10/C-ITS-Brochure-2020-FINAL.pdf

Krugman, P., and Wells, R., "Microeconomics", New York, 2004.

Lytrivis, P., "How Physical and Digital Infrastructure can support CCAM – INFRAMIX findings", EU CAD Conference 2021,
https://www.connectedautomateddriving.eu/eucad2021/programme/#pres

Kulmala, R, *et al*., "Road map for developing road operator core business utilizing connectivity and automation MANTRA Deliverable D5.2", 2020.

Qualcomm. "ITS Stack 80-PE732-64 Rev A", 2019.
https://www.qualcomm.com/media/documents/files/c-v2x-its-stack.pdf

Riegelhuth, G., "Introduction – road operators strategy view",
Presentation at URSA MAJOR 2 Workshop "The interface from TMPs to navigation services", Frankfurt, 2016-04-28.
www.its-platform.eu.

Riegelhuth, G., "The Strategy of Road Operators considering C-ITS Day 2+ services",
Car2Car Forum 2020, 2020-11-03
www.car-2-car.org

SAE International "Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles J3216_202005", 2020.

Satu Innamaa, "NordicWay 2 Evaluation Report", 2020.
https://www.nordicway.net/

Shi, E., Gasser, T., "User communication – What does automated driving actually mean?", 2017
https://www.bast.de/BASt_2017/EN/Automotive_Engineering/Subjects

Shi, E., Gasser, T., Seeck, A., and Auerswald, R., "The Principles of Operation Framework: A Comprehensive Classification Concept for Automated Driving Functions,"

SAE Intl. J CAV 3(1):27-37, 2020
https://doi.org/10.4271/12-03-01-0003
Sundberg, J, *.et al*., "D4 Roadmap Recommended Actions for Core Network Corridor Digitalization", 2020.
Technavio, "Vehicle-to-Everything V2X-communication system market industry analysis", 2019
https://www.technavio.com/report/
Tool, O., and Verweij, F., "(CODECS) Deliverable 4.1 Update Website Report on State - of - the - Art Strategy for C-ITS Deployment," 2017.
http://www.codecs-project.eu/index.php?id=32
University of Valencia, PIARC Special Project "Smart Roads Classification", Proposal, 2021
Van der Linden, G., "Sustainable and Smart Mobility Strategy – How Road Infrastructure can support Automated Driving", EU CAD Conference 2021, 2021.
https://www.connectedautomateddriving.eu/eucad2021/
Viktorsson, C., Roberg, C., "White Paper for (future) C-ITS service implementation – roles and responsibilities for C-ITS, EU EIP Deliverable D3 of Sub-Activity 4.4", 2019.
Volny, M., "Message architecture beyond initial deployment phase", in: Drees, H. et al., Webinar Documentation – Profiles: Lessons learned and Perspectives, CODECS Deliverable D2.5, 2018.
Yoshida, J., " "Mode Confusion" vexes drivers, carmakers", 09.02.2021,
https://www.eetimes.com/mode-confusion-vexes-drivers-carmakers/

# Appendix 1: Communication technologies for C-ITS

There are two types of vehicle-to-everything (V2X) communication technologies depending on the underlying technology being used:

- WLAN-based and
- Cellular based

**WLAN based**

- **802.11p (ITS G5)**
  Dedicated short-range communications (DSRC) are one-way or two-way short-range to medium-range wireless communication channels specifically designed for automotive use with a matching set of protocols and standards.

- **WLAN technology**
  V2X communication has originally used WLAN technology for direct communication between vehicles and vehicles (V2V) and traffic infrastructure (V2I) for when two V2X senders come within each other's range creating what is called a vehicular ad hoc network. It does not require any communication infrastructure in place for vehicles to communicate, which is seen as key to assure safety in remote or less developed areas.[63] The radio technology is part of the WLAN IEEE 802.11 family of standards and known in the US as Wireless Access in Vehicular Environments (WAVE) and in Europe as ITS-G5.

**Cellular based**

- **3GPP (C-V2X)**
  More recent V2X communication uses cellular networks and is called cellular V2X (or C-V2X) to differentiate it from the WLAN-based V2X. There are multiple industry organizations, such as the 5G Automotive Association (5GAA), promoting C-V2X.
  - C-V2X is initially defined as LTE in 3GPP Release 14 and is designed to operate in several modes:
  - Device-to-device (V2V or V2I) and Device-to-network (V2N)

[63] https://www.technavio.com/report/vehicle-to-everything-v2x-communication-system-market-industry-analysis?utm_source=pressrelease&utm_medium=bw&utm_campaign=t9_wk27&utm_content=IRTNTR31488,accessed 2021-01-04.

- C-V2X is a unified technology platform which integrates:
  - Short-range, network-less, direct communications (LTE-V2X PC5, as of today)
  - Long-range cellular network communications (LTE-V2X Uu, as of today)

C-V2X includes support of both direct communication between vehicles (V2V) and traditional cellular-network based communication which can provide a migration path to 5G based systems and services. In a newer 3GPP Release number 15 the V2X functionalities are expanded to support 5G. The direct communication between vehicle and other devices (V2V, V2I) uses a so-called PC5 interface. PC5 refers to a reference point where the User Equipment (UE), i.e. mobile device, directly communicates with another UE over the direct channel in which communication with a fixed base station is not required.

**Uu-CSP, long-range cellular Uu interface (C-V2X)**

Uu refers to the logical interface between the UE and the base station. This is generally referred to as vehicle-to-network (V2N). V2X allows the C-V2X device to use the cellular network connection in the traditional manner over Uu interface. Similar to WLAN based V2X also in case of C-V2X, two communication radios are required to be able to communicate simultaneously via a PC5 interface with nearby stations and via the UU interface with the network. While 3GPP defines the data transport features that enable V2X, it does not include V2X semantic content but proposes usage of ITS-G5 standards like CAM, DENM, BSM, etc over 3GPP V2X data transport features.[64]

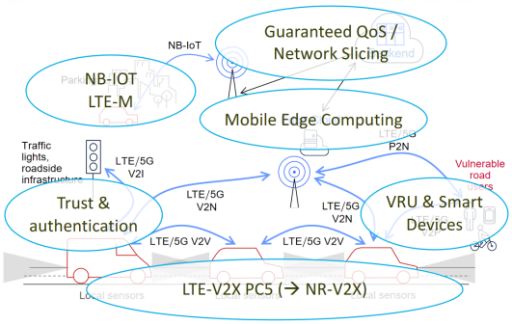



**Figure 17 Automotive Connectivity Landscape**
**Source: 5GAA power point presentation, 2019.[65]**

[64] https://www.3gpp.org/release-15 accessed 2021-01-04.
[65] https://5g-ppp.eu/wp-content/uploads/2019/01/2.-5GAA-FLAMENT-5G-vertical-WS_120219.pdf, accessed 2020-12-23

# Appendix 2: The CCAM evolution in Europe

According to ERTRAC (2019) Connected Automated Driving (CAD) must take a key role in the European Transport policy, since it can support several of its objectives and societal challenges, such as road safety, congestion, decarbonization, social inclusiveness. ERTRAC believes that automated driving should be understood as a process taking place in parallel and possibly in integration with other important evolution of road transport: the electrification of the powertrains, and the multiplication of mobility offers, especially shared mobility concepts. The overall efficiency of the transport system can be much increased thanks to automation. Traffic safety is of key importance for connected automated driving: to ensure safe interaction with all road-users in mixed traffic environments, in particular with vulnerable road users (VRU) and motorcycles. The ERTRAC roadmap for Connected Automated Driving therefore contributes to their long-term vision for the transport system where they believe that by 2050, vehicles should be electrified, automated and shared.[66]

C-ITS is important for automated and connected driving and mobility in that it provides a service platform where all the different stakeholders can work together to provide better services. A key initiative is the European Commission's launch of the **Cooperative, Connected, Automated and Autonomous Mobility (CCAM)** Single Platform which represents a Commission Expert Group consisting of both private and public stakeholders.[67] The aim of this platform is to advise and support the commission within the area of open road testing and making the link to pre-deployment activities. This is done through the coordination of CCAM research, piloting, testing and deployment activities, in order to increase their efficiency and effectiveness as well as integrate existing fora. The group will also address any issues related to data access and exchange, digital and road transport infrastructure, communication technology, cybersecurity and road safety.[68]

The table below summarises the key topics and associated results of the CCAM Platform so far. Generally, all working groups have worked on the key topics resulting in scoping papers that have concluded with recommendations for the next steps. A particularity of WG 1 on the EU R&I Agenda has been that the WG results by end of 2019 early 2020

[66] ERTRAC (European Road Transport Research Advisory Council), "Connected Automated Driving Roadmap," 2019.

[67] https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?do=groupDetail.groupDetail&groupID=3657

[68] https://connectedautomateddriving.eu/mediaroom/european-commission-launches-ccam-single-platform/ accessed 2020-12-30.

have provided the sound basis for ramping up the CCAM Partnership. This has resulted in the closure of the Platform WG 1 in favour of the CCAM Partnership in May 2020.

**Table 4: CCAM Platform key topics and results**

| Working Group | Key Topics/Results |
|---|---|
| **WG 1: Develop an EU agenda for testing** | Vision, objectives, scope and R&I areas for the CCAM Partnership |
| **WG 2: Coordination and cooperation of R&I and testing activities** | Knowledge Base, Common Evaluation Methodology and Test Data Sharing Framework |
| **WG 3: Physical and digital road infrastructure** | List of attributes of the physical and digital infrastructure, Matrix of PDI attributes mapped to generic driving tasks (sense, plan, act) |
| **WG 4: Road safety** | Research priorities for road safety, analysis of on-going experimentation (best practices, lessons learned and gap for road test and pre-deployment) and national legal framework used for allowing experimentation and testing of Automated vehicles and potential convergence. |
| **WG 5: Cybersecurity and access to in-vehicle data linked to CCAM** | Learnings, gaps and actor collaboration to ensure security of CCAM vehicles against cyber threats (secure access and exchange, technical and legal issues for the access, transfer, sharing, use and storage of data. high quality standards and accuracy of data) |
| **WG 6: Connectivity and digital infrastructure for CCAM** | Appropriate mix of in-vehicle sensors and communication for CCAM, exemplified by three use cases (emergency braking in traffic jam, VRU/pedestrians in urban environment, lane merging on highways), applying project criteria, incl. technology options for connectivity-based solutions and help clarifying further testing needs on interoperability, spectrum and coexistence, with a view to ensuring future-proof solutions. |

The CCAM Partnership is a collaboration within Horizon Europe (2021-2027), bundling the R&I efforts on Connected Cooperative and Automated Mobility (CCAM). The European Commission and important actors (vehicle manufacturing industry including their supply chain, telecom industry, road authorities and operators on national, regional and urban scale, universities and research institutions) agree on the R&I related needs (such as a co-programmed partnership). The agreement is framed formally by a Memorandum of Understanding between COM and the actors, and content wise by a Strategic Research and Innovation Agenda (SRIA). SRIA agenda comprises the entire decade since the results of the last Horizon Europe projects starting in 2027 will most likely be available close to or within the year 2030.

The CCAM Partnership represents one out of approximately 50 European partnerships within Horizon Europe. The CCAM partnership belongs to Horizon Europe Cluster 5,

bundling all partnerships related to climate, energy and transport issues.[69] The CCAM Partnership is part of the package in which a Memoranda of Understanding between COM and cross-sector partners have been signed during the R&I Days of June, 2021.

According to COM, European Partnerships will:[70]

- Address complex challenges outlined in Horizon Europe, such as accelerating the transitions towards a society and economy that are climate neutral and circular
- Support the achievement of EU priorities, such as the European Green Deal, a Europe fit for the digital age, an economy that works for people, and a stronger Europe in the world
- Be impact-driven by deploying a broad range of R&I activities, from concept to demonstration and validation, to those supporting market, regulatory and societal uptake
- Contribute to a stronger European Research Area (ERA) by avoiding the duplication of efforts, creating critical scales of investment and enhancing synergies between programmes

The following figures depict the different challenges and its subjects that are worked on within the Horizon Europe partnership together with an overview of the different sectors that are represented within the CCAM Association as of 2020.

[69] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe_en, accessed 2021-08-12.

[70] European Commission, "Horizon Europe – The next generation of European Partnerships, Factsheet", February 2021, https://op.europa.eu/en/publication-detail/-/publication/3f2505fb-8864-11eb-ac4c-01aa75ed71a1

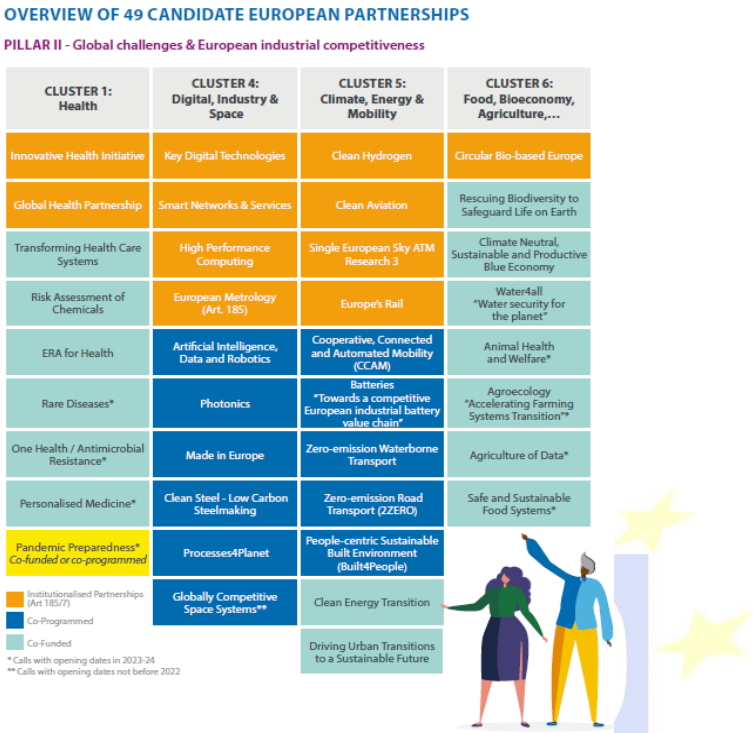



**Figure 18 European Partnerships in Horizon Europe**
**Source: Directorate– General for Research and Innovation, European Commission**[71]

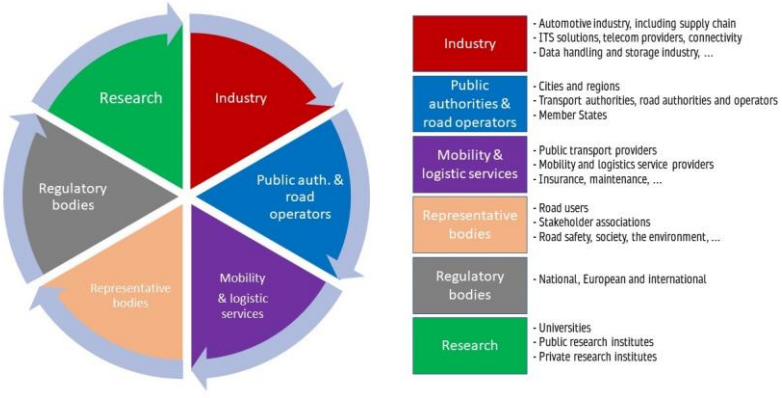



**Figure 19 Membership of the CCAM Association (CCAM 2020)**

[71] https://op.europa.eu/en/publication-detail/-/publication/3f2505fb-8864-11eb-ac4c-01aa75ed71a1 accessed 2021-08-12

The interests of the various partners are bundled in the newly established CCAM Association, a non-profit association under Belgian law.[72] At the time of writing October 2021 around 160 members have joined the CCAM Association. Among others, national transport authorities, road authorities and road operators form one membership category (out of 15). Nearly half of the beneficiaries of EU EIP (including designated Implementing Bodies) are already members of the CCAM Association. The SRIA as longer-term document links to expected impacts of the partnership to a goal system. The objectives get more concretized in several steps (general, specific and operational). The objectives are also linked to KPIs in order to monitor the implementation progress until 2030.

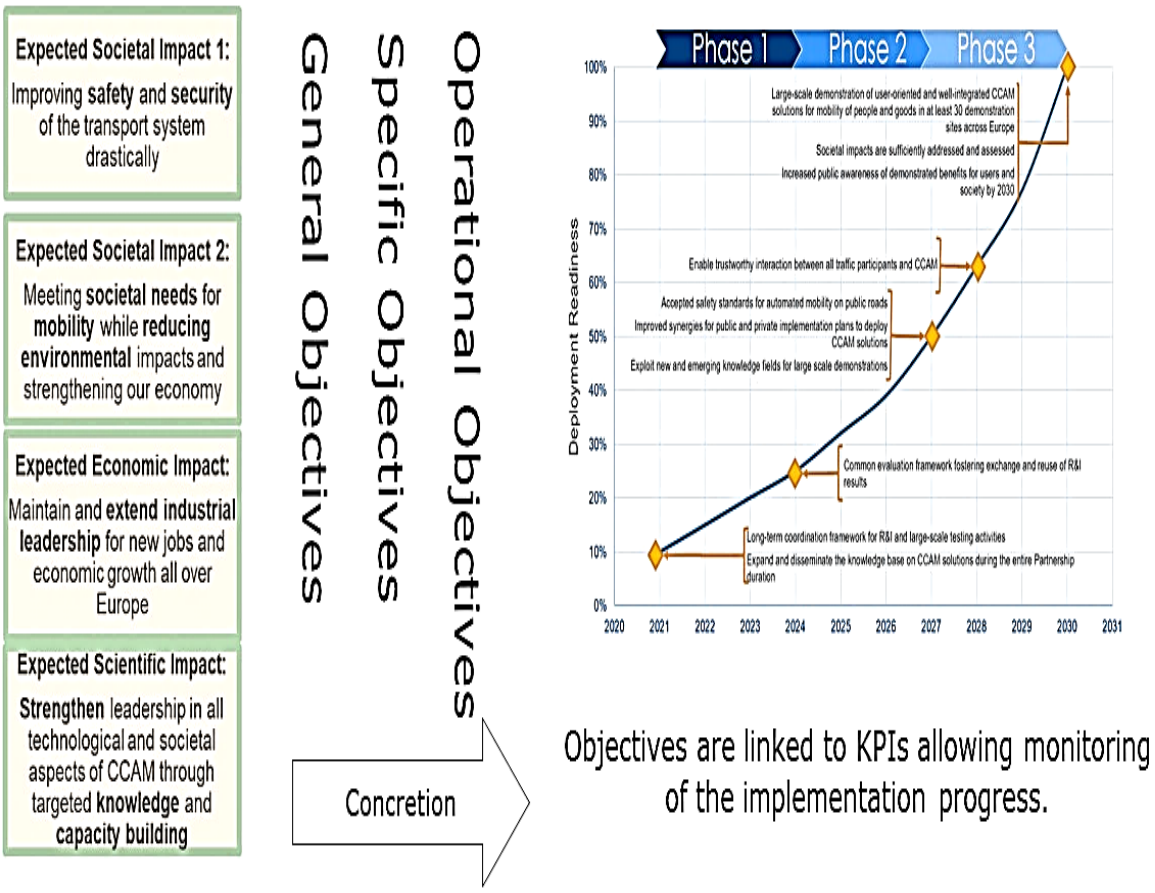



**Figure 20 Expected Impacts, goal system and progress monitoring (authors own illustration based on SRIA elements)**

[72] https://www.ertrac.org/uploads/images/CCAM%20Association%20Statutes%20presentation%2003-11-2020.pdf, accessed 2021-08-13.

Moreover, the research and innovation needs are allocated in seven clusters, involving technology development as well as validation, impact assessment and research coordination. The cluster 4 (Integrating the vehicle in the transport system) is pivotal for road authorities and operators because it contains all research topics devoted to Physical and Digital Infrastructure, Connectivity and C-ITS as well as Fleet and Traffic Management within an CCAM ecosystem. The SRIA expects the interaction with the other clusters being as follows:

- The actions advance during the CCAM Partnership timeline towards testing and implementation in Cluster 1. Expected outcomes of the first actions will allow for implementing specific elements after the first phase of the CCAM Partnership.
- At the same time, it is expected that R&I actions of the technology clusters (Cluster 2 and 5) will deliver important results on e.g., improved sensor and in-vehicle decision making capabilities as well as how cybersecurity can be best embraced in order to allow and achieve a transport system integration of vehicles, infrastructure, user and overarching entities.
- These inputs, including progressing the state-of-play on core R&I topics of Cluster 4 itself, will stimulate a second wave of Innovation Actions. This wave aims at advancing the technical maturity and putting more emphasis on the organisational implications of the proposed solutions, all to drive the integration of vehicles in the transport system. The second wave targets on delivering mature results ready for testing and implementation in the final third phase of the programme.

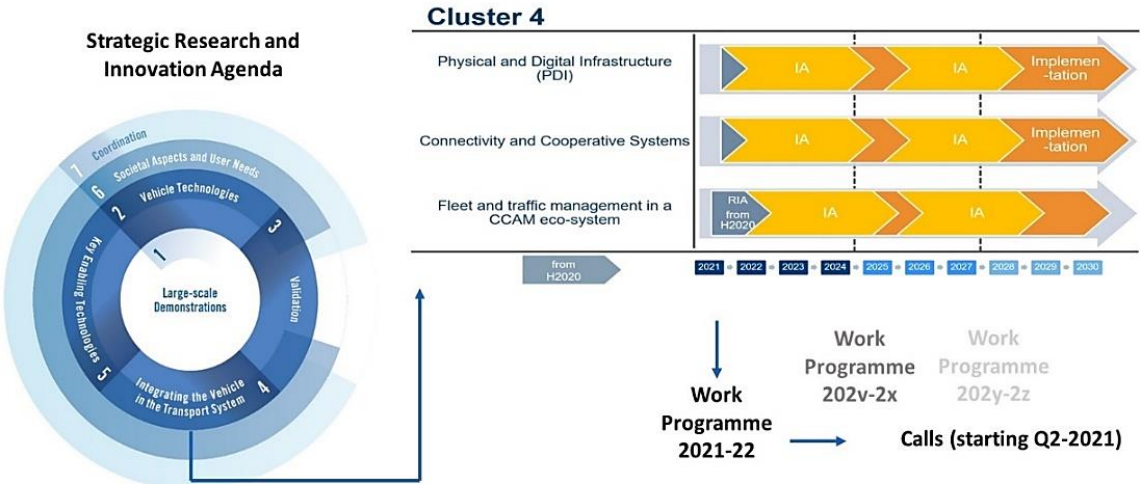



**Figure 21 R&I clusters and addressing topics in Work Programmes and research calls (authors illustration based on SRIA elements)**

# Appendix 3: Taxonomies for CCAM

Connectivity and cooperative systems are important enablers for a higher level of automation. A truly safe automated driving will according to SAE International (formerly the Society of Automotive Engineers) depend on defining the comprehensive list of overlapping conditions an autonomous vehicle (AV) might encounter into what is called the operational design domain (ODD).[73] ODDs are operating conditions under which a driving automation system, or feature, is designed specifically to function according to certain environmental, geographical, and time-of-day restrictions and/or certain traffic or roadway characteristics (SAEJ3016).[74] [75] The ODD is relevant to all levels of automation except for 0 (No Driving Automation) and 5 (Full Driving Automation), since the attributes of the ODD are directly connected to the way the automated driving system works. It is up to the manufacturers of the system to specify the ODD for their automated driving system, but a coordinated approach is the most promising.

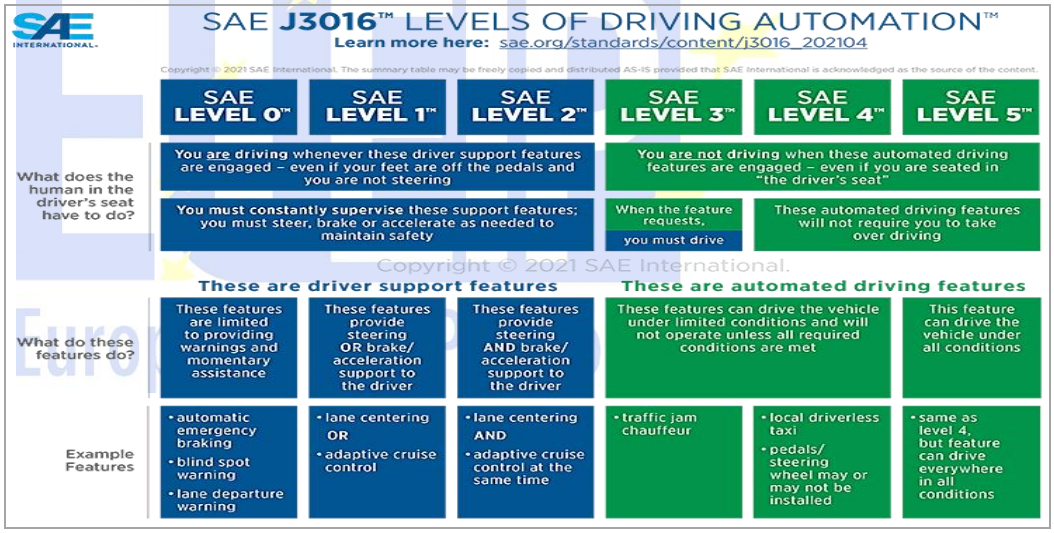



**Figure 22 SAE J3016 Levels of driving automation**
**Source: SAE international, 2019**[76]

[73] https://www.sae.org/news/2019/11/odds-for-av-testing, accessed 2021-01-04
[74] https://www.sae.org/standards/content/j3016_202104/, accessed 2021-08-06
[75] https://www.sae.org/standards/content/j3216_202005/ accessed 2021-04-05
[76] https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic, accessed 2021-08-06

While SAE J3016 is the worldwide leading taxonomy for levels of sustained, continuous, automation there have been efforts to put the taxonomy in a wider and also more user focused context:

- Well-established Advanced Driver Assistance Systems (ADAS) functions on the market today, e.g., “Autonomous Emergency Braking”, “Frontal Collision Warning” or “Lane Departure Warning” cannot be assigned to the terms of the sustained/continuous principle of operation described by SAE. The same is true for “Emergency Assist” functions that intervene in case of pathologically induced paralysis or temporary incapacitation and have the objective of returning the vehicle to a comparatively risk-minimal-condition. As a result, sustained/continuous automation is embedded in a wider functional automation landscape which also comprises information and warning (principle of operation A) and temporarily intervening functions in accident-prone situations (principle of operation C). Sustained/continuous automation as in SAE J3016 is then labelled as “principle of operation B”).[77] [78]

| Principle of Operation A: Informing and warning | Principle of Operation B: Continuously automating | Principle of Operation C: temporarily intervening in accident-prone situations |
|---|---|---|
| 1. Status information | Take direct influence on vehicle guidance. | Autonomous intervention… |
| 2. Warning (abstract hazard) | Conscious activation by the driver. | I. …in abstract hazards |
| 3. Warning (concrete hazard) | Always overrideable. | II. …in concrete hazards |

**Figure 23 Superordinate Principles of Operation (with regard to vehicle automation)**

- A frequent issue among users interacting with automation functions is mode confusion[79] and following from this, confusion about users responsibilities when alternating the driving task with a machine or relying on machine performance while

[77] Gasser, T., Frey, A., Seeck, A., Auerswald, R., “Comprehensive Definitions for Automated Driving and ADAS”, Paper 17-0380, Proceedings of 25th ESV Conference, Detroit 2017, https://www-esv.nhtsa.dot.gov/Proceedings/25/25ESV-000380.pdf, accessed 2021-08-23.

[78] Shi, E., Gasser, T., Seeck, A., and Auerswald, R., "The Principles of Operation Framework: A Comprehensive Classification Concept for Automated Driving Functions," SAE Intl. J CAV 3(1):27-37, 2020, https://doi.org/10.4271/12-03-01-0003, accessed 2021-08-23.

[79] Yoshida, J., ““Mode Confusion” vexes drivers, carmakers”, 09.02.2021, https://www.eetimes.com/mode-confusion-vexes-drivers-carmakers/#, accessed 2021-08-23.

it actually only offers some sort of superior assistance. The taxonomy on user communication of automation modes distinguishes three modes:[80]

- Assisted mode: Once activated, the system supports the driver in performing the driving task. Irrespective of the extent of support, the driver must constantly monitor the system and the environment.
  Example: BMW Driving Assistant Professional, Tesla Autopilot.
- Automated mode: While the system is driving the vehicle, the driver can engage in non-driving related tasks. The prerequisite is that the driver remains receptive to requests from the system that demands the driver to take over the driving task again. The system offers the driver sufficient time to resume the driving task (e.g., Audi AI traffic jam pilot).
- Autonomous mode: The system operates the vehicle. People on board are passengers and have no driving tasks.
  Example: autonomous buses in Monheim (Northrhine-Westphalia, Germany).

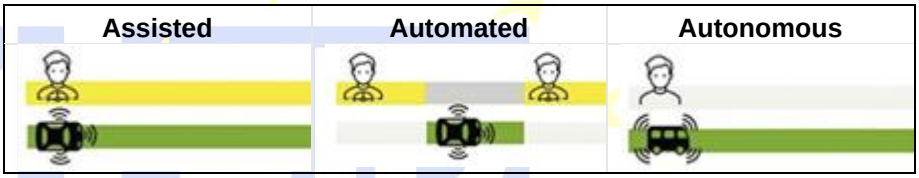



**Figure 24 User communication of automation modes**

Back to SAE J3016 as a leading taxonomy for automation SAE International also points towards the cooperation and connectivity aspect which is important for enabling mobility applications that are not achievable by individual automated driving system (ADS)-operated vehicles operating independently of each other. Hence, SAE J3216 complements SAE J3016 by providing a taxonomy and definitions for Cooperative Driving Automation.[81] [82] The key element of the taxonomy lies in the distinction of several cooperation classes and further on in the mapping against the automation levels. The classes of Cooperative Driving are labelled as follows:

- No cooperative automation

[80] Shi, E., Gasser, T., "User communication – What does automated driving actually mean?", https://www.bast.de/BASt_2017/EN/Automotive_Engineering/Subjects/f4-user-communication.html?nn=1844934, accessed 2021-08-23.

[81] SAE International, "Taxonomy and Definitions for Terms related to Cooperative Driving Automation for On-Road Motor Vehicles", SAE J3216, Issued 2020-05, https://www.sae.org/standards/content/j3216_202005/, accessed 2021-08-23.

[82] Dopart, K., U.S. DOT "Cooperative Driving Automation Research", SIP-adus Workshop 2020, https://www.sip-adus.go.jp/evt/workshop2020/file/cv/07CV_04_Dopart.pdf, accessed 2021-08-23.

- Class A: Status-sharing
  “Here I am and what I see” (e.g., Brake Lights, Traffic Signal)
- Class B: Intent-sharing
  “This is what I plan to do” (e.g., Turn Signal, Merge)
- Class C: Agreement-seeking
  “Let’s do this together” (e.g., Hand Signals, Merge)
- Class D: Prescriptive
  “I will do as directed” (e.g., Hand Signals, Lane Assignment by Officials)

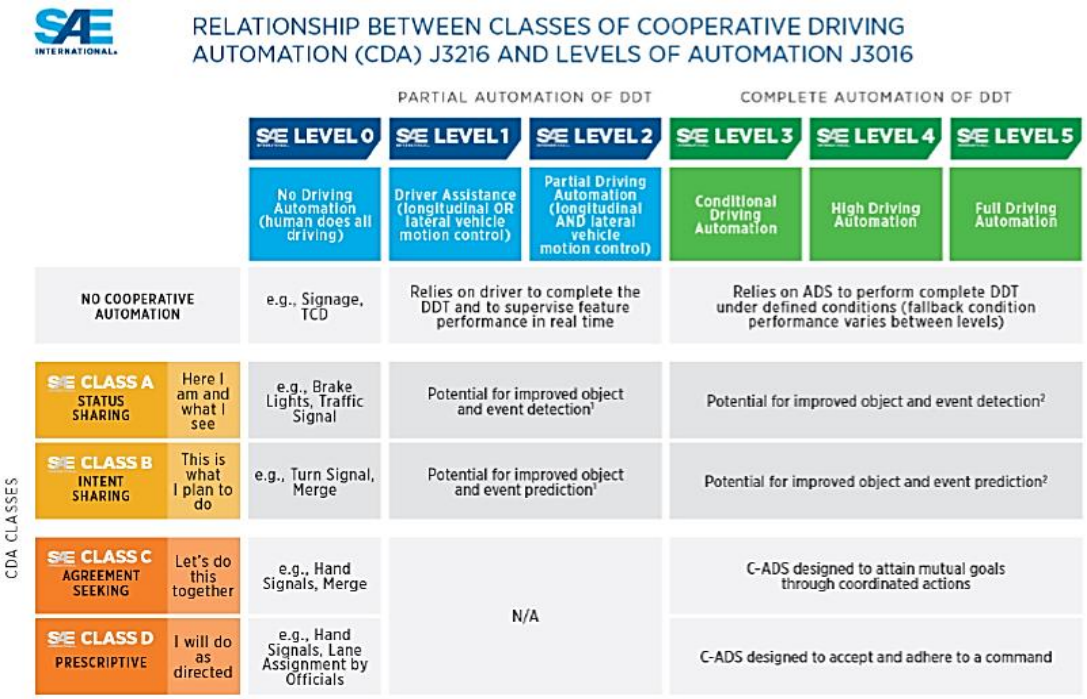



**Figure 25 Relationship between classes of Cooperative Driving (SAE J3216) and levels of Automation (SAE J3016) (Dopart 2020)**

It is noteworthy that the classes of Cooperative Driving correspond well to the logic of the sense-plan-act which is also pivotal to the PDI matrix work in WG 3 of the CCAM Platform (see chapter 2.6) and to the phased roadmap approach as it is represented in the chapter on the industry driven perspectives (see chapter 3.2).

As argued above, it is crucial for automated vehicles to dispose of Operational Design Domains (ODD) of sufficient length in order to generate meaningful impacts and benefits for users (e.g., slots where the driver can pay attention to other productive or

regenerating tasks). Information from road infrastructure can greatly help to extend the knowledge of vehicles of situations ahead of and around its position beyond the range of on-board sensors. This has led to the taxonomy of Infrastructure Support for Automated Driving (ISAD) as developed by the INFRAMIX project (H 2020, 2017-2020).[83] [84]

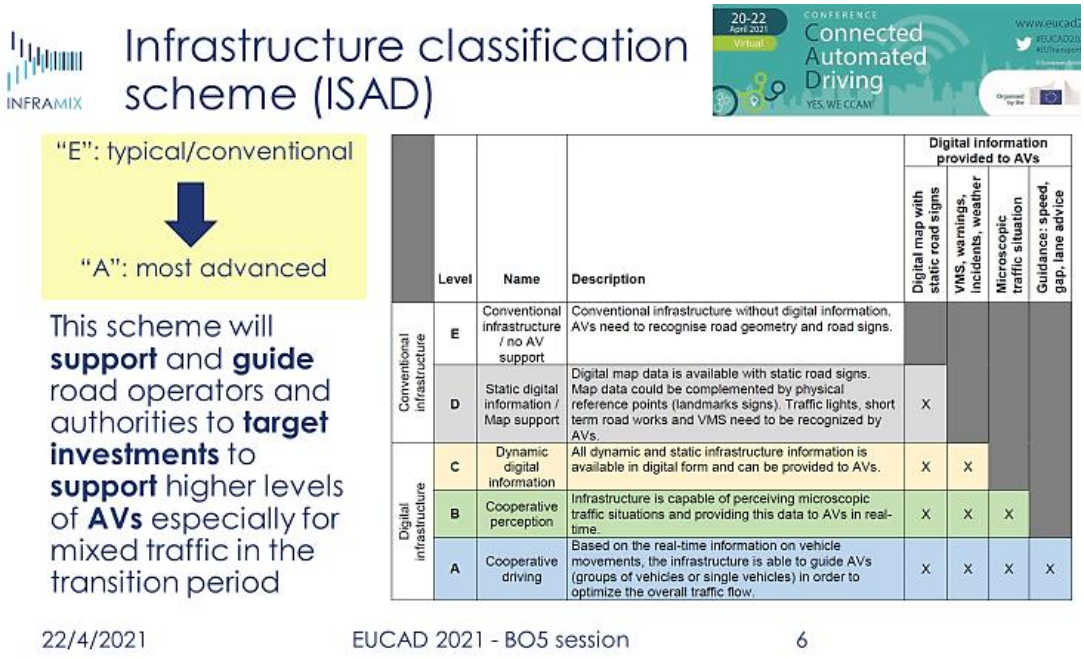



**Figure 26 Purpose and Taxonomy of Infrastructure Support for Automated Driving (ISAD, Lytrivis 2021)[85]**

European ITS Platform

Similar to the taxonomies previously discussed the infrastructure support is also classified in levels, from the conventional infrastructure providing no extra support for automated vehicles (E) to the most advanced digital infrastructure enabling cooperative driving manoeuvres (A). The motivation for levels is related to the aspect of structure and classification. They are intended to serve as a guiding star to target investments of road authorities and operators. The implications of the ISAD taxonomy and more widely the

[83] General information on INFRAMIX, https://www.inframix.eu/, ISAD-specific: Carreras, A., Daura, X., Erhart, J., Ruehrup, S., "Road infrastructure support levels for automated driving, EU-TP 1488", 25th ITS World Congress, Copenhagen 2018

[84] https://www.inframix.eu/wp-content/uploads/ITSWC2018-ASF-AAE-Final-paper_v4.pdf, accessed 2021-08-25

[85] Lytrivis, P., "How Physical and Digital Infrastructure can support CCAM – INFRAMIX findings", EU CAD Conference 2021, https://www.connectedautomateddriving.eu/eucad2021/programme/#pres, accessed 2021-08-25.

impacts of digital infrastructure for automated vehicles and the CCAM system in general are discussed more extensively in other EU EIP reports and elsewhere (e.g., MANTRA project, CEDR Transnational Research Program 2018-2020).

A recently developed proposal for a smart roads classification (SRC) complements the ISAD taxonomy by Levels of Service for Automated Driving (LOSAD).[86] [87]

- The LOSAD classification aims at expressing the readiness of a road section to host automation. This readiness has to be understood as a dynamic parameter since e.g., frequent disengagements of automation functions (for reasons to be understood) and/or adverse weather conditions can temporarily limit the capabilities of the roads section to host automation.
- LOSAD is proposed – similarly to ISAD – consisting of five levels from the lowest (E) to the highest (A). In the lowest level, the operational road section would be too short or patchy to enable a comfortable automated driving experience or there are not any operational section. In the highest level, vehicles can be driven in high automation mode continuously and safely. For the purpose of this overview it is neglectable how exactly the levels are defined.
- The two classifications interact by LOSAD expressing the (dynamic) capabilities of the road (made up by physical and partly digital infrastructure) and ISAD indicating the connectivity and cooperation capabilities added to the road (by means of digital infrastructure). Both classifications interact and form – as a result – the smart roads classification (diamond shape).
- The smart road classification distinguishes between Humanway, Assistedway, Automatedway, Full Automatedway and Autonomousway. The illustration of the results in a plain diagram leaves room for some additional remarks on the characteristics of the smart roads classes.

[86] University of Valencia, PIARC Special Project “Smart Roads Classification”, Proposal, 26.05.2021, https://poliformat.upv.es/access/content/user/24389381/Contenido%20abierto%20al%20p%C3%BAblico/PIARC/PIARC%20SRC%20Proposal%20Document%20for%20Q3%2020210526.pdf, accessed 2021-08-25

[87] García, A., F. J. Camacho and P. Padovani, “Examining the effect of road horizontal alignment on the speed of semi-automated vehicles”, Accident Analysis & Prevention, Vol. 146 (2020), Paper 105732, 2020, accessed 2021-08-25.

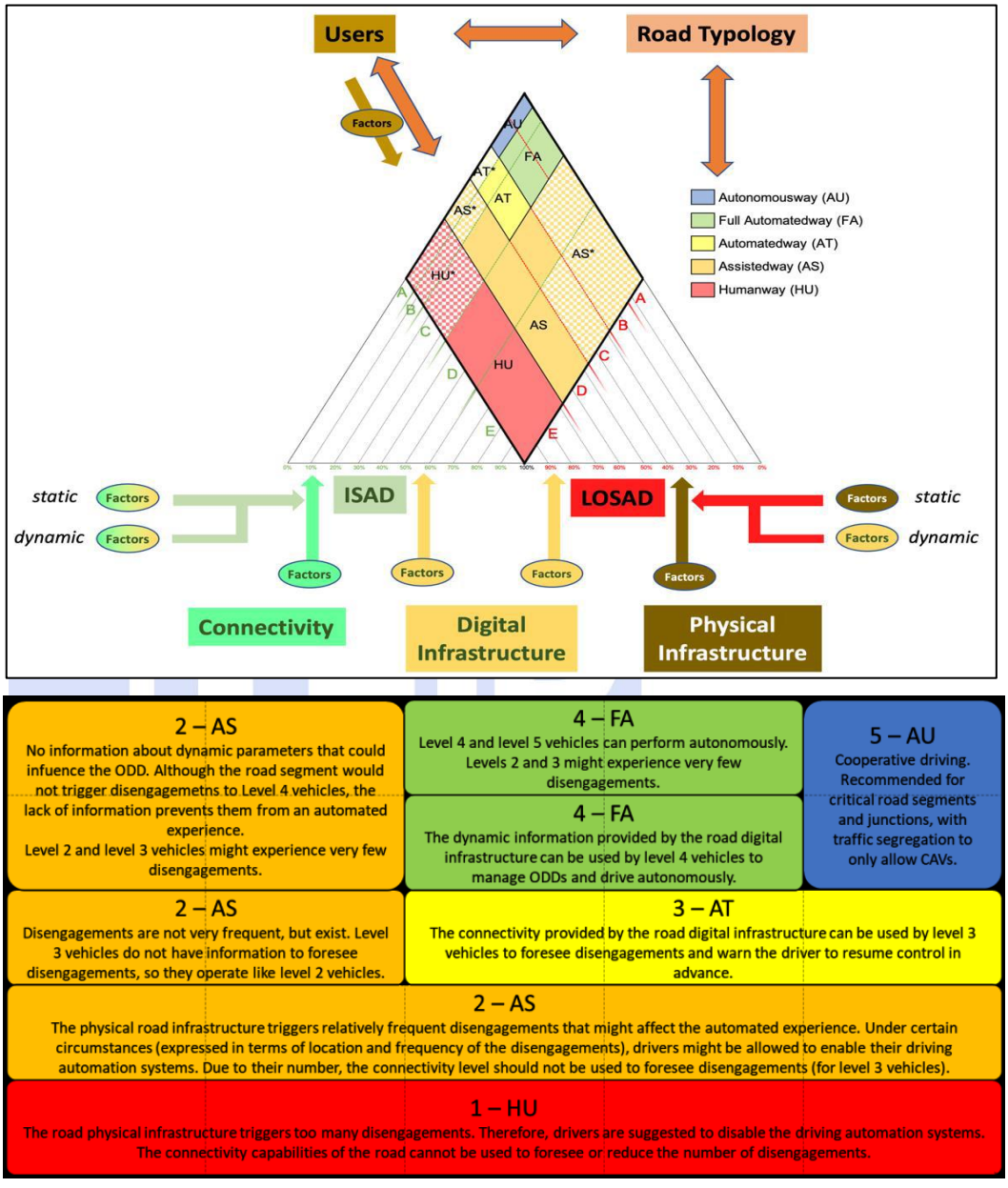



**Figure 27 Smart Roads Classification as a result of combining Levels of Service and Infrastructure Support for Automated Driving (LOSAD/ISAD)**
**Source: University of Valencia 2021, combining figures 3 and 4)**

When interpreting the results of the Smart Roads Classification, it becomes obvious that the results match very well and in consistent manner with the other taxonomies featured in this section:

- The Smart Roads Classification is fully in line with the user communication for automation modes, as reported earlier in this chapter. The user communication does not explicitly refer to humanway since from the automation point of view it is no automation and hence out of scope. However, mentioning humanway explicitly is beneficial for the sake of completeness. In the same way, the user communication taxonomy abstains from differentiating automated and full automated way. This distinction is important for infrastructure managers but not for users with a view to their roles, duties and liabilities when driving of being driven in a vehicle with some of full automation capabilities.
- The Smart Roads Classification is a result of complementing infrastructure resided concepts, i.e. Level of Service and Infrastructure Support for Automated Driving. Linking to the content of the SAE-led taxonomies on automation levels and cooperation classes (SAE J 3016 and 3216) leads to similar results which are illustrated below in the CCAM performance diagram.
- Moreover, it might be useful as a further step to investigate closer the integration possibilities of the taxonomies in a sort of meta-taxonomy leading to consistent results.

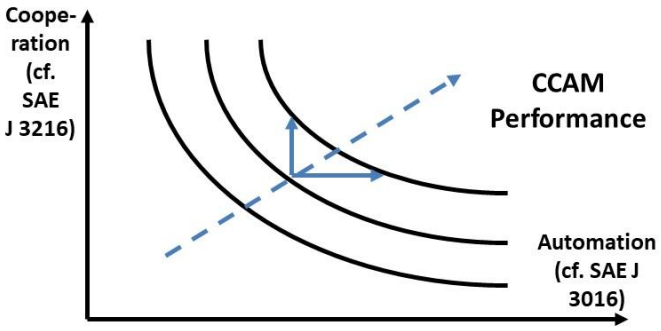



**Figure 28 CCAM performance (authors' illustration)**

With regard to the CCAM availability the result of (on-board) sensor and automation capabilities combined with the cooperation classes leads to a certain (level of) CCAM performance. The more comprehensive the automation and cooperation capabilities are, the higher is the achievable CCAM performance. CCAM performance can be understood as the "utility hill" of the automation-cooperation combinations. The CCAM performance diagram displays this concept in a plain diagram with outward performance levels being superior to inward performance level curves. The level curves apply the indifference

curves concept of standard microeconomics textbooks.[88] The diagram also allows for the following interpretations (for reference: consider any point on the middle performance curve):

- A fixed performance level can be achieved along the curve with varying ingredients. A vehicle with lower on-board sensor capabilities but higher cooperative capabilities (= towards higher left area) may perform equally well (matching functional safety requirements presupposed) compared to a vehicle with plenty of and/or high-performance sensors (= towards lower right area). In analogy, this is a matter of whether vehicles can rely only on own intelligence or on distributed intelligence in a CCAM system. Again, the issue of functional safety becomes relevant and is crucially important here.
- The CCAM performance can be improved by adding automation capabilities (while considering fixed cooperation capabilities). This implies a jump to next level of performance in horizontal direction. In a similar way, keeping automation fixed and adding cooperation capabilities would allow for the level jump in vertical direction. Of course, there can be also variations of both leading to the same next level jump. In principle, the argumentation remains also valid for reversing the argumentation, looking towards lower performance levels.

Summing up this argumentation, the CCAM performance levels approach leads to similar results like the engineering based taxonomies of LOSAD, ISAD and the resulting Smart Roads Classification. One could potentially argue that the CCAM performance levels are not needed when they only represent a second way of achieving the same. Such an argumentation would however overlook or underestimate the wider applicability of the CCAM performance levels approach. In a systemic view (which CCAM requires in the end), with coordinated investment across sectors, the CCAM performance approach offers – at least conceptually – the possibility of integrating seamlessly another important dimension. This common denominator of the automotive as well as of the infrastructure sector is costs, ultimately expressed in millions of Euros (or other currencies in Europe).

[88] E.g., Krugman, P., Wells, R., “Microeconomics”, New York 2004.

# Appendix 4: Summary of analysed roadmaps

The following table includes a summary of some of the views concerning the future development and needs of ITS, C-ITS and connected and automated driving as stated in some of the most relevant roadmaps identified throughout this study.

**Table 5: Relevant roadmaps**

| Actor and roadmap | Description |
|---|---|
| **Car2Car Communication Consortium Guidance for Day 2 and beyond roadmap** | The roadmap illustrates deployment phases (Day 1, Day 2, Day 3+…) alongside sample use cases according to communication services and message types as well as supporting functionalities such as security, misbehaviour detection and functional safety qualifiers. The roadmap also illustrates several dimensions of improvement throughout the deployment phases (e.g., on accuracy and timeliness). |
| **Euro NCAP Roadmap 2025 (C-ITS related)** | The Euro NCAP Roadmap 2025 lists V2X as to be integrated into the assessment programme by 2024.[89]<br>Together with the 'Advanced' Award for Volkswagen's car-to-x communication system in the Golf 8 [90] which clearly demonstrates the expectation of Euro NCAP for C-ITS to become a new pillar of automotive safety performance. |
| **EU EIP**<br>**D4 Road Map (ITS related)** | The EU EIP in their D4 Roadmap (Sundberg *et al*, 2020) highlight the policy side of C-ITS deployment in a Corridor network. As a supporting document to EU EIP roadmap, it highlights the actions required for C-ITS deployment in near future. Some parts of the report also talk about service harmonization which has gained momentum in recent years.[91]<br>One important element for a future development, as identified in the roadmap, is the role of the digital infrastructure in which the concept of digital twins will become increasingly important. There will be a need to discuss the concept of digital twins and their required properties among the stakeholders to agree on a common view on digital twins connected to their development, operation and management needs. |
| **ERTRAC Connected Automated Driving Roadmap (CCAM related)** | ERTRAC Connected Automated Driving Roadmap (March 2019) contains development paths and timeline for automation in three different categories of vehicles, these are used by several other initiatives as starting point. The roadmap highlights common definitions of automation levels and systems, challenges for the implementation of higher levels of automated driving functions, development paths are provided for three different categories of vehicles. |

[89] https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf

[90] https:/www.euroncap.com/en/press-media/press-releases/volkswagen-safety-technology-rewarded-by-euro-ncap, accessed 2021-03-20

[91] Jonas Sundberg et al., "D4 Roadmap Recommended Actions for Core Network Corridor Digitalization.," 2020.

| | |
|---|---|
| | By 2030 ERTRAC envisages that the following level 3 and level 4 use cases will be implemented on highways:<br>• Traffic Jam Chauffeur (cars and trucks)<br>• Highway Chauffeur (cars and trucks)<br>• Highway Autopilot including Highway Convoy<br>• Highway Pilot Platooning (trucks)<br>• Highly Automated Vehicles in Confined Areas (trucks)<br>• Highly Automated Vehicles Hub-to-hub operations (trucks)<br>• Highly Automated Vehicles on Open Roads (trucks)<br><br>The roadmap identifies the following needs that will need be addressed for future developments connected to CAD.<br>• What are the roles and responsibilities of the different stakeholders of PDI for CAD?<br>• Should the vehicle cope with any road infrastructure, and if not, what demands can be set to adapt the existing PDI?<br>• How and to what degree will joint concepts by automotive sector, fleet and road operators improve traffic management? |
| **MANTRA "Road map for developing road operator core business utilizing connectivity and automation" (CCAM related)** | The MANTRA[92] project consortium forecasts highly automated driving use cases in vehicle fleets by assessing the impacts of automated driving in relation to traffic flow, infrastructure, and road authority core business. The MANTRA roadmap contains a list of 92 actions in the domains of physical infrastructure, digital infrastructure, operations and services, and road planning and maintenance with regard to the possible impacts of highly automated driving by 2040, and their ODD-related requirements. |
| **The 5G Automotive Association (5GAA) (C-ITS related) "A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs, 5GAA"** | The 5G Automotive Association (5GAA) has identified the most promising advanced driving use cases in conjunction with the adoption of Cellular Vehicle-To-Everything (C-V2X) standards as well as availability of required technologies and devices, such as on-board units (OBUs), road-side units (RSUs), and smartphones.<br><br>The roadmap depicts the market trajectory of the identified use cases along with the expected timeline for their mass market deployment.<br><br>It also highlights the spectrum needs for basic and advanced driving use cases which corresponds to between 10 and 20 MHz at 5.9 GHz for basic safety, and an additional 40 MHz or more at 5.9 GHz for advanced driving. |

[92] The MANTRA acronym stands for *Making full use of automation for National Transport and Road Authorities – NRA Core Business*